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ABSTRACT

This curriculum guide provides resources that teachers and trainers can use to help learners improve their ability to apply technology problem-solving skills in the workplace. The instructional strategies and practice problems in the guide are patterned after those of the American College Testing (ACT) Work Keys System. Gains in skill levels can be measured by Work Keys assessments and by the assessment provided in this guide. The guide includes information that will help instructors offer learners opportunities to solve workplace problems that demonstrate the physical principles inherent in mechanical, electrical, fluid dynamic, and thermodynamic heat systems. The following information is discussed: Work Keys, applied technology, proficiency outcomes, problem solving, instructional strategies, using practice problems, pretesting and posttesting, resources for instructors, and resources for learners. The instructional strategies and practice problems are divided by Work Keys level for improving through Levels 3-6. Four appendixes contain the following: (1) a list of 9 references; (2) lists of applied technology resources, such as 44 sources of learning activities, 25 books for learners, 4 sources for instructional kits, 9 instructional computer software and laser disks, 11 suppliers of science resources and materials, and 18 Internet sites; (3) a list of basic scientific principles; and (4) selected Ohio Science Proficiency Outcomes for sixth-, ninth- and twelfth-grades.. (KC)

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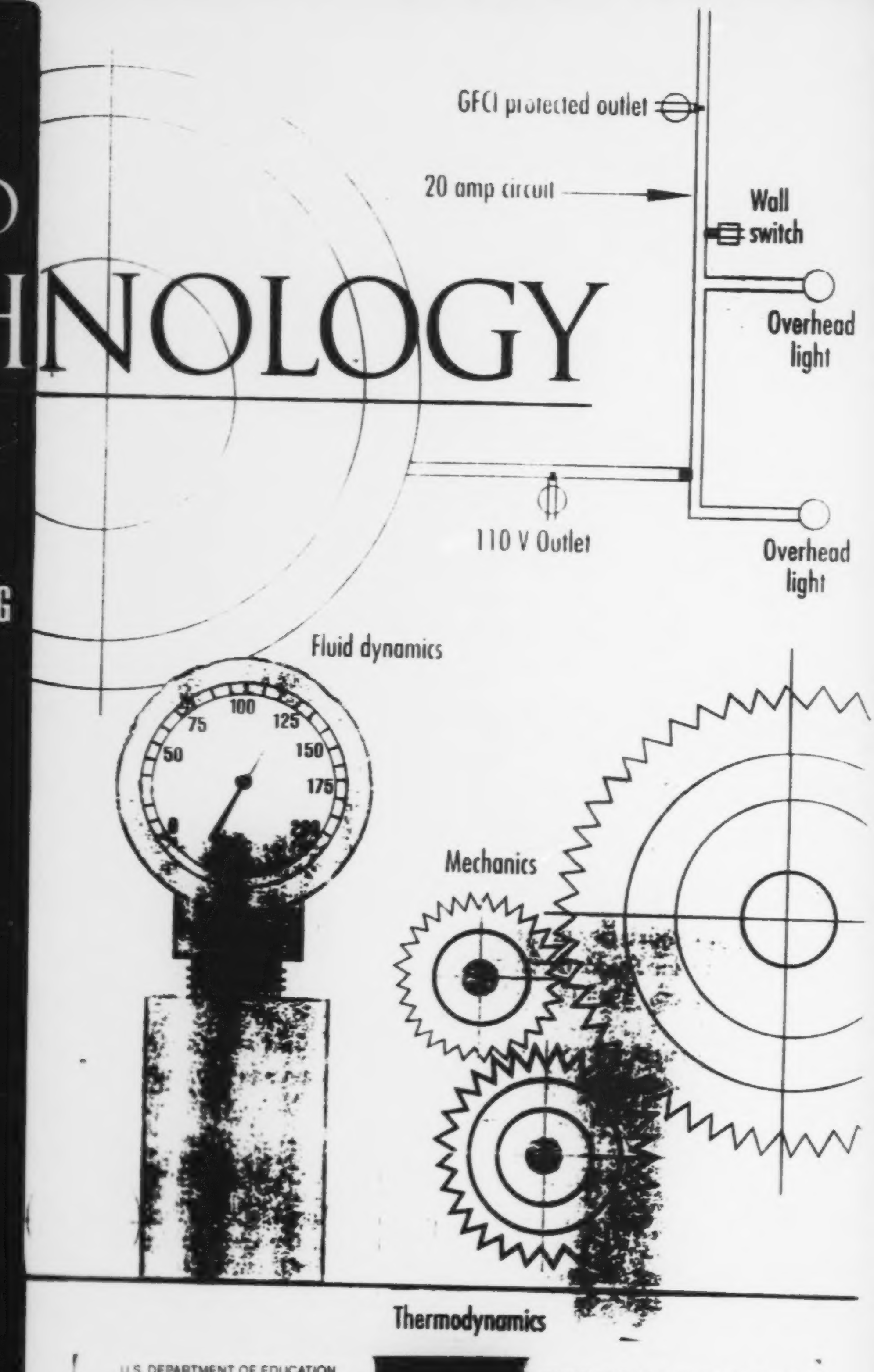
APPLIED TECHNOLOGY

TARGETS FOR LEARNING

PREPARING SUCCESSFUL PROBLEM SOLVERS IN THE WORKPLACE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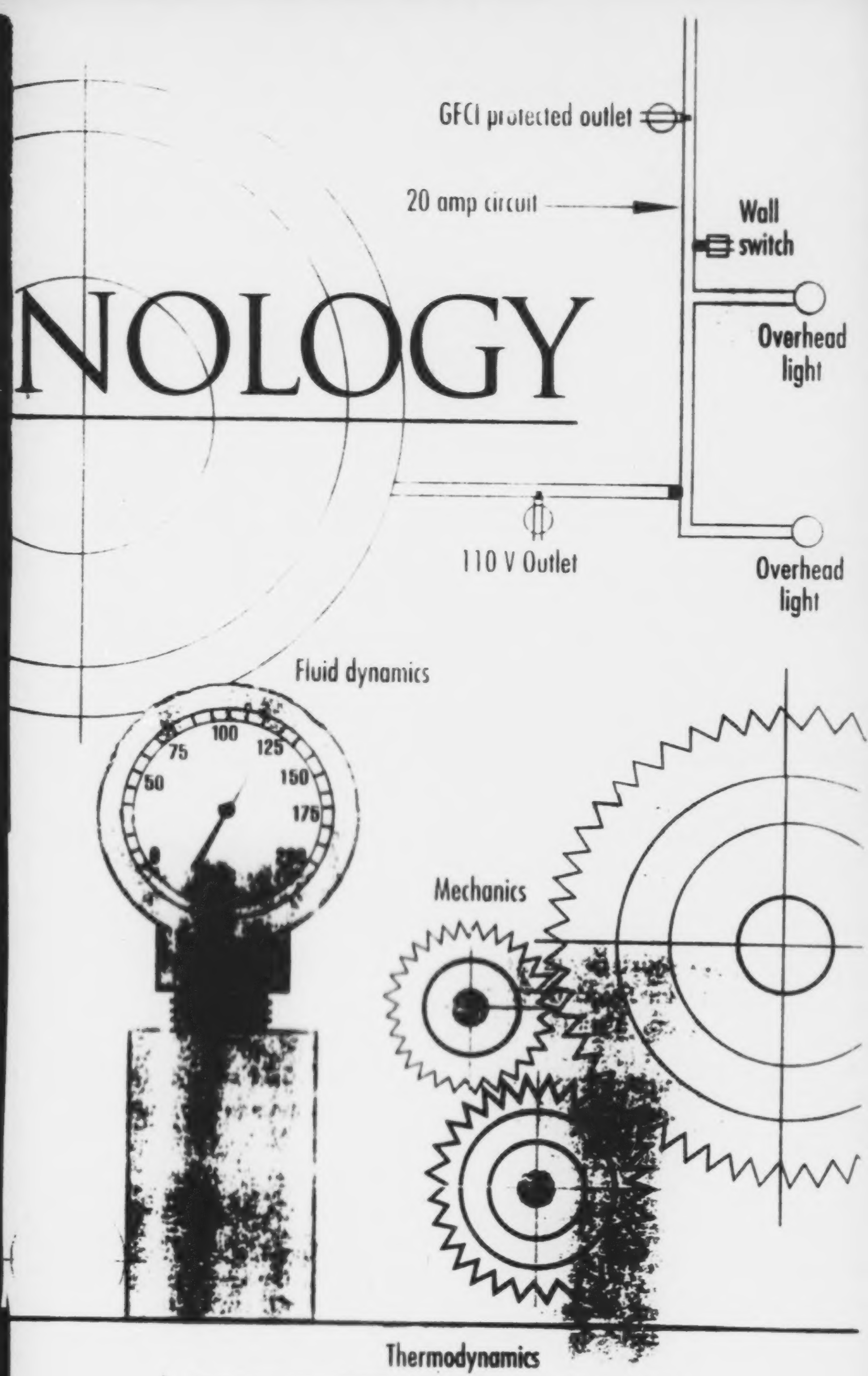
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Additions to Target Are Encouraged

The learning activities and practice problems in *Target for Learning: Applied Technology* were written by teachers, industry trainers, and industry employees. Targets was designed to be used by nonscience teachers and trainers. One reason why Targets was designed for a three-ring notebook format is that additional practice problems and learning activities can be added. As a user of Targets, you are encouraged to submit problems and activities that can be used in a supplement to this book. In addition, your comments about the problems and activities in this book are welcome. Submit these materials to Targets for Learning, Vocational Instructional Materials Laboratory, 1900 Kenny Road, Columbus, Ohio 43210.

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Project Overview

This book, *Targets for Learning: Applied Technology*, was developed as part of an Ohio School-to-Work Partnership Prototype grant. The project's goal was to develop resources that teachers and trainers could use to help learners improve their problem-solving skills in the context of the workplace. The instructional strategies and practice problems have been patterned after those of the ACT Work Keys System. Gains in skill levels can be measured by Work Keys assessments.

During the project, both *Targets for Learning: Applied Technology* and *Targets for Learning: Applied Mathematics* were—

- Written by teachers and industry representatives
- Piloted by vocational teachers, applied academics teachers, and industry trainers
- Modified to reflect what was learned during piloting

Both books are distributed by The Ohio State University's Vocational Instructional Materials Laboratory, which is part of the Center on Education and Training for Employment. The sales office can be reached by calling 800/848-4815 or faxing 614/292-1260.

In addition, the Vocational Instructional Materials Laboratory can provide teachers and trainers with coaching and training that will prepare them to effectively use these materials. For further information, contact the VIML directly at 800/848-4815 or 614/292-5001.

Acknowledgments

Many people have committed their time and talents to help make this book a useful resource for educators and trainers who wish to give learners opportunities to solve authentic applied technology problems.

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Contents

Project Overview iii

Acknowledgments v

About This Book 1

Overview of the Work Keys System 3

About Applied Technology 5

Why Should I Teach Applied Technology? 9

What Makes a Learning Activity Effective? 11
  The Five Es of Instruction 14

When Teaching or Training Through Inquiry, What is My Role? 17

Questions For Applied Technology Instructors 19

What Can I Do to Help Learners Improve in Applied Technology? 23
  Process Skills Descriptions and Self-Check for Instructors 24

Problem-Solving Strategies 25
  Problem Solving Activity 1: Designing and Building 26
  Problem Solving Activity 2: Building Things That Do Something 28
  Problem-Solving Activity 3: Black Boxes—Predicting What's in the Box 31

Gender Equity: What Can I Do? 33

Where Do I Begin? 35

How Should I Structure Learning Activities? 38

Assessment 45
  Checklist of Learner's Process Skills and Content-Area Knowledge 49
  Summary Sheet of Learners' Process Skills and Content-Area Knowledge 52

Level 3 Instructional Strategies and Problems 55

Level 4 Instructional Strategies and Problems 119

Level 5 Instructional Strategies and Problems 189

Level 6 Instructional Strategies and Problems 265

Appendix A: References .305

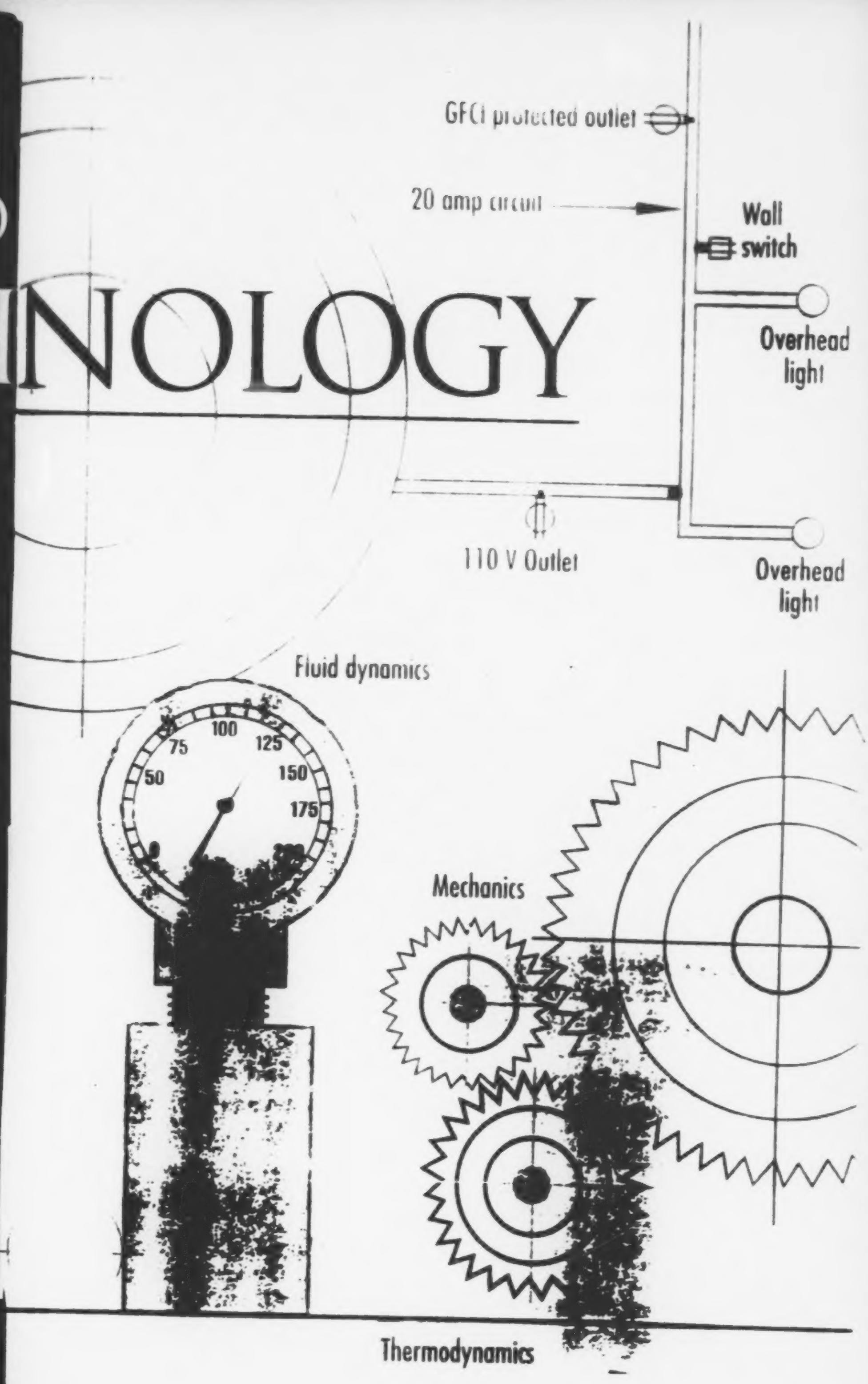
Appendix B: Applied Technology Resources .307
  Resources for Instructors of Applied Technology .307
  Books for Learners .317
  Instructional Kits .320
  Instructional Computer Software and Laser Disks .321
  Suppliers of Science Resources and Materials .323
  Internet Sites .325

Appendix C: Basic Scientific Principles .327
  Generalizations that Can be Made About Mechanics .328
  Generalizations that Can be Made About Electricity .330
  Generalizations that Can be Made About Heat .331
  Generalizations that Can be Made About Fluids .331

Appendix D: Selected Science Proficiency Outcomes .335
  Selected Sixth-Grade Science Proficiency Outcomes .335
  Selected Ninth-Grade Science Proficiency Outcomes .336
  Selected Twelfth-Grade Science Proficiency Outcomes .337

APPLIED TECHNOLOGY

TARGETS FOR LEARNING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About This Book

Targets for Learning: Applied Technology was developed because most teachers and industry trainers don't have the time or the expertise to develop strategies for preparing people to be problem solvers with workplace technology. The following will help you to understand what this resource is all about:

- Targets for Learning was written for **nonscience teachers**. You don't need to have formal training in physics or other science areas to make full use of this book. However, even formally trained physics teachers will find value in this book's practical focus on applications in the workplace.

- Targets for Learning gives instructors and trainers a **brief background** about the primary scientific principles that are involved in the Targets problems. However, this book does not provide in-depth information about those principles. Nor does it offer a comprehensive list of the scientific principles involved in solving technological problems—such a list does not exist. (Refer to Appendix C on pp. 327-331 for a list of principles that was compiled by instructors who piloted Targets.)

- The skills addressed in *Targets for Learning: Applied Technology* are meant for **all learners**—not just those who are studying in technical areas (e.g., mechanics, manufacturing, electronics, construction). At home and at work, almost all people encounter and need to solve technology-related problems. A few such challenges are fixing toys and bicycles, operating copy machines, computers, and VCRs, and repairing toilets.

- Targets for Learning **supports what instructors are already doing** by offering ideas and materials for achieving their current goals and objectives. It is not a new program or a new curriculum—it is a resource that complements existing instructional efforts.

- Targets for Learning is not meant to be a complete curriculum. Instead, it **supplements the curriculum** by giving educators and trainers a wide variety of practice problems to use as needed.

- *Targets for Learning: Applied Technology* was developed with consideration for the National Science Education Standards and the Benchmarks for Science Literacy. It is meant to help learners become more effective problem solvers, which involves process skills that have been identified in **national standards** and are measured by state proficiency tests.

- Each section of Targets for Learning notes the specific **Ohio Science Proficiency Outcomes** that it addresses.

- Targets for Learning was designed to reflect the format of the **ACT Work Keys System**, which is described on pp. 3-8.

- The activities in *Targets for Learning: Applied Technology* give learners opportunities to solve workplace problems that demonstrate the physical principles inherent in **mechanical, electrical, fluid dynamic, and thermodynamic (heat) systems**.

- Targets for Learning is presented in a 3-ring binder to enhance its usefulness to instructors. Users may wish to—
  - ✔ Change the order of the lessons to meet learners' needs and experiences
  - ✔ Add materials from other sources
  - ✔ Include personal notes about the instructional strategies used to teach the concepts and processes involved in applied technology

Targets for Learning: Applied Technology includes a wide variety of information that will help you, as an instructor, offer learners highly effective instructional experiences. Targets provides you with information and insights about—

- Work Keys
- Applied technology
- Proficiency outcomes
- Problem solving
- Instructional strategies
- Using practice problems
- Pretesting and posttesting
- Resources for instructors
- Resources for learners

The learning activities and practice problems are divided by Work Keys *level* and are categorized by *technological principle* (e.g., mechanics, electricity, fluid dynamics, thermodynamics). An index of problems is included for each level.

Overview of the Work Keys System

Targets for Learning: Applied Technology is designed to help instructors prepare learners to solve technological problems in the workplace. The Targets for Learning materials were developed using the guidelines set forth in the Work Keys System. Work Keys is a national system for teaching and assessing workplace academic skills in secondary, postsecondary, and adult training programs. It was developed by American College Testing (ACT) to provide educators and employers with a system for measuring the skill levels of employees and of students (who are prospective employees). In addition, the Work Keys System gives educators, employers, and learners a common language for understanding and discussing the skills and skill levels that are required to successfully perform specific jobs. The Work Keys System has three components:

- **Profiling** uses job analysis to identify the skills and the level of those skills that are needed to succeed in *specific jobs or occupations.*

- **Assessments** measure the level of those same skills in *individuals.* Assessments are developed by ACT and administered by schools and Work Keys satellite centers. In Ohio, all vocational students take three Work Keys assessments at the beginning of their junior year and at the end of the senior year. In addition, adults in Ohio take Work Keys assessments at adult vocational full-service centers, which serve as the primary Work Keys satellite centers.

- **Instructional support** helps educators and trainers supplement and reinforce their existing curriculum and instruction to address the workplace requirements more directly. ACT published *Targets for Instruction* to give educators and trainers guidelines for developing effective interventions for learners who need to improve their skill levels. Those guidelines were used by the authors of the Targets for Learning instructional materials.

All of the *Targets for Instruction* books can be purchased through The Ohio State University's Vocational Instructional Materials Laboratory, which is part of the Center on Education and Training for Employment. The sales office can be reached by calling 800/848-4815 or faxing 614/292-1260.

Additional information about Work Keys can be obtained directly from ACT at 800/553-6244.

About Applied Technology

ACT defines applied technology as "the skill of applying principles of technology to practical problems." Applied technology "involves the basic technological principles of mechanics, electricity, fluid dynamics, and thermodynamics (heat) as they apply to machines, equipment, and mechanical systems found in the workplace."[1] In order to teach these principles, instructors can help learners understand how each of these systems is affected by power source, flow, pressure, and resistance.

Work Keys measures four levels of complexity, 3 through 6, with Level 3 being the least complex and Level 6 being the most complex. Although Level 3 is the least complex, it represents a level of applied technology skill that is still well above having no skill at all. The levels build on each other, each incorporating the skills of the preceding levels.

Applied technology is important for all learners, not just those planning to work directly with technology. When you stop to think about it, employees in almost all jobs need to know how to solve technology-related problems in order to succeed at work. Consider the last time the copy machine had a paper jam or needed more toner. The person who fixed it was probably not an engineer or a technician. That person was, however, able to solve a problem that involved a mechanical system. And the demands of problem solving don't end at work. People are called on to solve many problems at home, including the following:

- Fixing a bicycle chain or putting together a computer table involves problem solving with mechanical systems.
- Hooking up a VCR to a television set or connecting the components of a stereo system involves problem solving with electrical systems.
- Determining a sprinkler system's placement in order to water the intended zones involves problem solving with a fluid system.
- Selecting the color of roofing shingles involves problem solving with a thermal system.

The applied technology skills required of workers at each Work Keys level are listed on the following pages. This information was summarized from ACT's book, *Targets for Instruction*, which provides more detailed information about each level as well as examples of problems at each level.

The instructors who are most successful at helping learners improve their skills with applied technology are those who understand the differences between problems at different levels and help their students to do the same. When learners understand how problems are leveled, they can compare their own problem-solving skills with those specified, which helps them set goals and assess their own accomplishments.

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[1] *Targets for Instruction*, Applied Technology, p. 16.

Level 3 learners can

1. Apply elementary principles underlying the operation of technological systems (mechanics, electricity, fluid dynamics, and thermodynamics) to solve problems within those systems.
2. Understand the operation of basic hand tools and simple electrical tools, subsystems of basic machines, and uncomplicated systems.
3. Recognize obvious symptoms when diagnosing a problem.
4. Determine, with efficiency and logic, what to check first when faced with a malfunctioning system or machine that contains 2-5 components that are potential sources of the problem.
5. Select appropriate methods or materials needed to solve problems that involve a one-step solution or solution path.

Characteristics of Level 3 problems

- Problems involve one uncomplicated object or system.
- Objects are often encountered at home or work.
- If a system is malfunctioning, the symptom is obvious and the solution path is straightforward.

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Level 4 learners can

1. Apply elementary principles underlying the operation of physical systems to solve a problem (e.g. identifying the effect of resistance on flow, such as valves in water pipes, volume controls in radios, and dimmer switches in light circuits).
2. Understand physical principles that are more abstract, less intuitive, and less observable than those at Level 3 (e.g., the flow of electricity is more abstract than the flow of water).
3. Understand the operation of moderately complex tools, machines, or systems, such as home appliances, pulley-driven equipment, or piping systems that carry more than one fluid.
4. Use reading for information and locating information skills as needed.
5. Recognize and identify information relevant to solving the problem while disregarding extraneous information.
6. Determine, as efficiently as possible, what to check first when inspecting a malfunctioning system or machine containing up to 10 components that are potential sources of the problem.
7. Solve problèms that require a two-step process or that involve the manipulation of two variables to arrive at a solution.

Characteristics of Level 4 problems

- Problems involve a two-step process or more than one variable.
- Problems contain some extraneous information and jargon.
- Objects may or may not be encountered at home or work (e.g., Level 3 may involve force and friction using an electric drill, and Level 4 may involve force and friction using a drill press).
- If a system is malfunctioning, the symptom may not be obvious and the solution path is not as straightforward as in Level 3. There are more possible solutions than in Level 3 problems.

Level 5 learners can

1. Use the basic principles of mechanics, electricity, fluid dynamics, and thermodynamics in moderate and advanced applications.
2. Understand complex machines and systems (e.g., operation of gas engines, complex appliances, or an electrical system in a building).
3. Solve problems that include a larger problem space, more extraneous information, and more technical terms than those at Level 4.
4. Manipulate 2 or 3 variables within a system to solve a problem.
5. Reduce the problem space to the point of knowing what to check first when inspecting a malfunctioning system or machine that could contain more than 10 potential sources of the problem.
6. Evaluate multiple solutions to determine the best solution for each problem. The available resources and needed resources must be considered.

Characteristics of Level 5 problems

- Problems involve several mechanical principles interacting with one another (e.g., a house, its thermostat, and its furnace).
- Problems contain more variables, solution paths, extraneous information, and technical jargon.
- Objects are probably not encountered at home or work.
- Advanced problem-solving skills are required. More complicated systems must be broken down into manageable parts.
- The source of the malfunction is fairly obvious compared to the other possibilities, but there are more possible, realistic solutions.
- Solutions may require computations.

Level 6 learners can

1. Use the principles of mechanics, electricity, fluid dynamics, and thermodynamics in advanced applications (e.g., repairing air-conditioning units, troubleshooting problems with automobile hydraulic lifts, reconfiguring wiring, making modifications on a bicycle with two sprockets to maximize performance).
2. Use subtle, less visible clues to determine the source of the problem with a machine or tool. (Information is gathered by sight, sound, smell, experience, etc.)
3. Troubleshoot complex systems in which a variety of mechanical, electrical, flow, or thermal faults are potential sources of difficult problems.
4. Choose the appropriate tool or piece of diagnostic equipment to accomplish a certain task.

Characteristics of Level 6 problems

- Problems involve several mechanical principles and complex equipment that interact with one another.
- Problems contain many variables and solution paths and much extraneous information and technical jargon.
- Advanced problem-solving skills are required. A larger volume of information than Level 5 must be interpreted when forming and testing numerous hypotheses to diagnose problems correctly.
- The learner must interpret an increased amount of information and deal with more potential problem sources when solving a problem.
- Learner must have knowledge of physical principles and must draw on diagnostic experience to reduce a large problem space. Finding the successful solution depends not only on determining how a machine or tool is malfunctioning but also on understanding how that malfunction impacts the other interrelated systems (e.g., a car mechanic using a variety of strategies to diagnose and repair a complex malfunction).

The following chart provides a summary of the Work Keys applied technology problem characteristics:

Summary of Work Keys Applied Technology Levels

Components of technological problems	Level 3	Level 4	Level 5	Level 6
Complexity of technological systems involved in the problem	uncomplicated	moderately complex	complex	complex
Principles of physics that workers are required to apply	elementary	elementary	moderate to advanced	advanced
Number of systems involved in the problem	one	two	two or more	two or more

As you can see from this information about the Work Keys applied technology levels, there is a great deal of overlap between levels. In addition, there is no clear indication of the content that learners need to know. More specifically, there is not a list of technological systems, scientific principles, or equipment that learners should master in order to score at a given level. Because of the breadth of the content included in applied technology, it is important that instructors help learners understand that they can not master **every** system, principle, and piece of equipment that exists in the workplace. Instead, they can develop their problem-solving skills through practice—by solving problems that involve **some** of those systems, principles, and equipment. Then, when asked to solve other problems, they will be able to bring the skills they have developed to those new situations.

Now that you understand more about Work Keys and applied technology, let's move on to see how you might teach others about solving technological problems.

Why Should I Teach Applied Technology?

Most instructors would agree that the primary purpose of education is to help learners succeed at work, at home, and in their community. And few would argue that people need to be effective solvers of technology-related problems in order to succeed at work and in other areas of life. In fact, the Secretary's Commission on Achieving Necessary Skills (SCANS) found that effective workers need to productively use all of the following:

- **Resources** (e.g., allocating time, money, materials, space, and staff)
- **Interpersonal skills** (e.g., working in teams, teaching others, serving customers, leading, negotiating, and working well with people from culturally diverse backgrounds)
- **Information** (e.g., acquiring and evaluating data, organizing and maintaining files, interpreting and communicating, and using computers to process information) Systems (e.g., understanding social, organizational, and technological systems; monitoring and correcting performance; designing or improving systems)
- **Technology** (e.g., selecting equipment and tools, applying technology to specific tasks, maintaining and troubleshooting equipment)

In addition, SCANS identifies a three-part foundation of skills and personal qualities needed for solid job performance—

- **Basic skills** (reading, writing, math, speaking, and listening)
- **Thinking skills** (thinking creatively, making decisions, solving problems, and knowing how to learn)
- **Personal qualities** (individual responsibility, self-esteem, sociability, self-management, and integrity)

When you stop to think about it, by helping learners solve technology-related problems in the workplace, instructors are helping them develop and practice **many** of the skills identified in the SCANS report. In other words, by helping learners become more effective at solving technological problems in the workplace, instructors will be helping them develop skills that will allow them to become more effective workers.

What Makes a Learning Activity Effective?

Take a two or three minutes to think about your experiences with science and/or technology education. In the space below, list at least 10 words that describe what you **didn't** like about how you were taught these subjects.

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________
6. ______________________________
7. ______________________________
8. ______________________________
9. ______________________________
10. ______________________________

Now think about what you **did** like about your science and/or technology experiences in school. Use the space below to write at least 10 words that describe the positive aspects of your education in these subjects.

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________
6. ______________________________
7. ______________________________
8. ______________________________
9. ______________________________
10. ______________________________

In most cases, individuals' experiences are similar to researchers' findings. Let's find out if your experiences and perceptions are similar to those of others across the country.

Most people find that their "didn't like" list matches fairly closely with the characteristics of ***traditional science and technology education***. Traditional instruction usually follows a prescribed sequence of activities, as follows:

- Introduction to the topic through a lecture, or a lecture and discussion
- One or more textbook reading assignments
- A lab experiment or activity that involves learners working alone and following specific instructions, using a limited amount of materials, and striving to find a predetermined or "correct" answer
- A lab report or other written statement of the findings
- A written quiz or test that indicates to the instructor whether or not the content was learned

In the traditional instructional format, there is not much room for learners to share ideas, make decisions, or understand the "big picture." For this and other reasons, many people do not learn well in the traditional setting. In addition, as a result of their experiences with traditional instruction, many high school students choose to not take advanced science, math, and technology courses, which may greatly affect their career options later in life. Take a minute to compare your "didn't like" list with the characteristics of traditional science and technology education.

Luckily, instructors are learning that there are more effective ways to help people learn. In recent years, educators have spent a great deal of time, energy, and resources to determine the content and processes involved in effective science and technology education.[2] A review of the related literature clearly indicates that successful science and technology education curricula should give learners a wide range of learning experiences that emphasize the following:[3]

- Responsible decision-making in real-world contexts
- Real-world doing (i.e., hands-on, minds-on)
- Individual and group performance
- Learner self-evaluation
- Curriculum-embedded assessment
- Cooperative planning by learners and leaders
- Interdisciplinary connections
- Learning from concrete to abstract and from familiar to unfamiliar
- Learning from the local setting to the global setting

[2] For more detailed information about educational standards for science, math, and technology education, refer to the National Research Council's *National Science Education Standards* (1996), the National Council of Teachers of Mathematics's *Curriculum and Evaluation Standards for School Mathematics* (1989), and the American Association for the Advancement of Science/Project 2061's *Science for All Americans* (1990) and *Benchmarks for Science Literacy* (1993).

[3] *Ohio's Model Competency-Based Science Program: Scientific Literacy for the 21st Century* (1994), p. 10.

It's likely that some of the things you did and didn't like about your science and technology education are listed above and some that are not. Keep reading—for more insights about effective instruction.

It is clear that no one type or combination of instructional strategies or activities is best for facilitating learning. In order to structure a curriculum that takes these suggestions into account, **instructors are encouraged to use many different strategies that get learners actively involved in the teaching-learning process**. The instructional strategies and practice problems in Targets for Learning provide instructors with a wide variety of real-world, hands-on learning experiences that can be used to promote successful learning in the classroom.

Now let's take these suggestions even further by making a bold statement: **To maximize learning, instructional activities should provide opportunities for learners to do inquiry-based exploration**. That is, instructors should provide learners with opportunities to ask scientific questions and then answer those questions for themselves through investigations.[4] When structuring learning activities, instructors should keep in mind that inquiry-based instruction includes the characteristics that are listed below.[5]

If you're skeptical—if this sounds like educational rhetoric to you—be assured that it's not; please keep reading. In fact, you may find that your personal list of what you liked about your science and technology education at least partially matches the characteristics of inquiry-based instruction, which are listed below. (Many other people discover this.)

- Starts with questions
- Engages learners actively
- Concentrates on collection and use of evidence
- Requires clear expression (e.g., written and verbal communication)
- Uses a team approach
- Does not separate knowing from finding out
- Welcomes curiosity and rewards creativity
- De-emphasizes memorizing technical vocabulary

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[4] *Science With Reason* (1995) p. 7.

[5] *Benchmarks for Science Literacy* (1993) professional development CD-ROM.

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Inquiry-based learning is about putting the learner at the center of his or her own learning process. When learners are allowed to gain an understanding of the material **for themselves**, they are more likely to remember what they have learned. (Most people will agree that passive learning is much less effective than active learning. Think about how much easier it is to learn information that you experience in a lab format than it is when you are lectured to.)

In inquiry-based learning, the **instructor's role** is to coordinate the learning experience by—

- Determining the content that will be studied
- Organizing exploratory experiences for learners
- Facilitating question-asking
- Providing a framework for collecting information and making generalizations

An inquiry-based instructional model that many instructors have used with great success is the **Five Es of Instruction**, which is an expansion of the learning cycle. It is a model that can be used as a *format for structuring lessons* that allows people to learn through an inquiry-based process. The Five Es include the following components:

Engagement	How will you start the class and get students interested? What will be the "hook" that motivates your learners to want to know more about the topic at hand? Engagement usually involves learners in a thought-provoking or discrepant event. Often in science education, the engagement step helps learners become aware of their preconceived ideas about a given concept. (NOTE: This step is optional. Sometimes, the exploration activities are, themselves, "hooks.")
Exploration	What investigations, discussions, class activities, problem solving activities, and/or cooperative group activities will be used? In other words, what hands-on activities will guide learners to make observations and collect data? (NOTE: In this stage, learners are not given new vocabulary or explanations about what to expect or why things happened the way they did.)
Explanation	How will you help students analyze what they have learned/experienced? In this stage, your job is to help learners draw conclusions and form new ideas based on their observations and the patterns that surfaced during exploration. Traditional instructional strategies (e.g., demonstrations, short lectures, lecture-discussions, textbook assignments, group reports, video tapes, and library research) may be included at this time.
Evaluation	How are you going to assess student learning? In other words, how will you know that learners understand the concepts and processes being taught?
Extensions	What are the possibilities for future learning resulting from this lesson? Instructors help learners use what they learned to solve new problems.

The following example gives ideas for structuring applied technology learning activities with the Five Es.

Engagement

A teacher, wanting to introduce the principles of electricity to her ninth-grade students, began with a **discrepant event**. She asked students to predict what would happen when she touched 2 wires, which were attached to a battery, to a pickle. After the students offered a wide range of predictions, she poked each end of the pickle with one of the wires, and it lit up! She then told the students that they would have the opportunity to develop an explanation for why that happened.

Exploration

Immediately following the introduction, the teacher provided each student with a zip-type sandwich bag that contained a battery, 2 coated copper wires, a flashlight bulb, and masking tape. First, she challenged them to make the battery light up (and provided no further instructions). As students worked, the teacher walked around the room to observe what they were doing, to give hints to students who were "stuck," and to provide input and direction by asking open-ended questions (and not giving answers). The teacher also encouraged students to learn from each other. Next, she gave the students a worksheet titled "How many ways can you make a bulb light?" Students were asked to draw diagrams in 2 columns: "Ways the Bulb Lit" and "Ways the Bulb Did Not Light."

The next day, the teacher gave each student a zip-type sandwich bag containing 3 batteries, 8 coated copper wires, 4 flashlight bulbs, and masking tape. She challenged them to learn everything they could by connecting the materials (and provided no further instructions). As she circulated among the students, most of them highly motivated, she asked questions such as, "What would happen if you connected two or more bulbs?" and encouraged students to learn from each other with comments such as "Maybe Andrea can explain to you how she connected her bulbs."

For homework, students were asked to complete a worksheet on which they predicted which battery-wire-bulb configurations would make the bulb light and which would not.

Explanation

After the students had plenty of time for exploration, the teacher facilitated a class discussion. The students were asked to share what they had learned.

The teacher asked questions such as the following:

- ✔ "To light the bulb, what specific places on the battery must be touched?"
- ✔ "How could you get your bulb to shine brightly?"
- ✔ "How could you attach your bulbs so that they all light up?" and "Were they all equally bright?"

✔ "When two or more bulbs were attached, how could you get them to shine the brightest?"

✔ "What other observations did you make?"

✔ "Based on your observations, what conclusions can you give?

✔ "Suppose you had a string of Christmas tree lights and a bulb burned out. What would happen? Why? What would happen if appliances in your home were arranged like Christmas tree lights?"

The teacher guided the students to develop "rules," or generalizations, about many things, including the following:

- Metal ends of batteries, wires, and bulbs need to be joined together in order for the bulb to light (which the students labeled a circuit).
- Bulbs attached beside each other (which the students labeled series circuits) were brighter than those attached in a row (which the students labeled parallel circuits).
- The more batteries in a circuit, the brighter the bulbs glow.
- The more bulbs in a circuit, the dimmer the bulbs glow.

Evaluation

The teacher checked individual students' understanding of the principles of electricity by giving a quiz; the students needed reconstruct six electrical circuits from diagrams and explain how each circuit worked.

Extension

Once the students had a basic understanding of the primary electrical principles, they were assigned new tasks that required them to apply what they had learned to real-life situations. Their activities included making an electrical game board; designing a flashlight; and using empty food boxes to construct buildings that light up. By doing this type of "teaching" **after** students had explored the concepts for themselves, the teacher enabled the students to operationalize their understanding of the concepts.

When Teaching or Training Through Inquiry, What is My Role?

To work in the role of instructor once involved being the "bearer of information" or "imparter of knowledge." However, knowing all that we do about the best way to help people learn, your role as an instructor is more like that of a **facilitator**. You are there to direct and guide; to help learners question and interpret. Some of the responsibilities of instructors when facilitating are as follows:

- **Provide the foundation for learning experiences.** They are responsible for setting up learning activities, providing learners with objectives, and then encouraging learners to explore and learn for themselves.

- **Be a resource for learners.** By helping learners find answers for themselves and directing them to information sources, facilitators encourage learners to become more autonomous learners—and less reliant on instructors.

- **Maintain a safe environment** in which learners can experiment.

- **Lead discussions**—helping learners attain their goals without telling them the answers. By asking a learner to share her hypothesis, make predictions, and then test them, the facilitator is encouraging the learner to synthesize her own understanding and share that knowledge with their peers. Some questions that instructors might use to enable learners to express their ideas and reactions are[6]
    - ✔ "Are you saying that...?" (Asking about the learner's reasons)
    - ✔ "Why do you think...?" (Asking about the validity of the learner's statements)
    - ✔ "Couldn't it be right that...?" (Asking for supportive evidence)
    - ✔ "How do you know that ...?" (Asking for supportive evidence)
    - ✔ "How might we find out whether...?" (Asking for alternative possibilities)

- **Ask questions.** Believe it or not, this is one of the most difficult skills for instructors to develop. It takes a great deal of planning and effort to master the skill of questioning. Here are some strategies that many instructors have found helpful.
    - ✔ When conducting a discussion, **prepare several key questions** to get things rolling. This will also help assure that key points will be addressed.
    - ✔ Ask **open-ended questions**; avoid those that can be answered with "yes" or "no."

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[6] This list was adapted from Matthew Lipman's work, which is cited in *Science With Reason*, pp. 36-37.

- **Ask questions that require learners to think critically to explain their observations and draw conclusions.** For example, in addition to asking recall questions (e.g., "How many bulbs lit up with one battery?"), ask learners to explain what they have observed (e.g., "Why is there a limit to the number of bulbs that will light up with one battery?"); synthesize what they have learned (e.g., "What can you generalize about all circuits?"); develop predictions based on what they understand to be true (e.g., "What would you predict will happen when more batteries are used?"); and apply what they have learned to other situations (e.g., "When planning electrical circuitry for a new building, what do engineers need to consider?")

- Sometimes **answer a learner's question with a question.** This causes learners to think more critically and to solve problems on their own (or with other classmates).

- After asking individual or groups of learners a question, **allow 5-10 seconds of wait time** before talking, providing a hint, or calling on someone. This allows all learners to respond—even those who may be unsure of themselves and those who prefer to think answers through before talking about them.

- **Ask questions without bias.** Refer to the upcoming section called Gender Equity: What Can I Do? for ideas such as
  - ✔ Posing the *same number of questions* to both male and female learners
  - ✔ Asking the *same challenging questions* of both male and female learners
  - ✔ Following males' **and** females' answer to one question with a *second, more difficult question*

Specific examples of questions that applied technology instructors might ask of learners are provided in the next section.

Questions For Applied Technology Instructors

Instructors might ask the following open-ended questions when learners are **exploring scientific principles**:

1. "What would happen if ......?" For example, "What would happen if you added more batteries?"
2. "What makes you think that?"
3. "What else could you try, in order to find out?"
4. "What would you predict?"
5. "How do you know?"
6. "What isn't being considered?"
7. "What are the certainties and limitations?"
8. "What is or can be reasonably inferred?"
9. "What potential outcomes or precautions should be considered?"
10. "What do you need to consider in order to find things out?"

In addition to asking open-ended questions to help learners explore scientific principles, instructors can ask specific questions that will guide learners as they develop applied technology skills by **investigating systems**. Prompts from the following list[1] could guide instruction on practically any system:

1. "When this system is working, what does it do?"
2. "For this system to work, must it receive any input?"
3. "What, if any, output does this system produce?"
4. "Identify at least four parts of this system. Describe what each part does, and tell how each part contributes to the system as a whole."
5. "Choose an interesting part of the system and list at least four words or phrases that describe that part. Which, if any, of those words or phrases also describe the whole system?"
6. "Could any of the parts of this system be made of different material without affecting how the system works? Explain."
7. "Can any one part of the system do what the whole system does? Explain."
8. "Can you take a part from another system of the same kind and use it to replace a part in this system? If you do so, will this system work the way it does now?"
9. Identify at least two parts of this system that must interact if the system is to function. Describe how these parts interact. Could the parts of this system be arranged differently and the system still function?"

[1] *Benchmarks for Science Literacy* (1993) professional development CD-ROM.

10. "What is the boundary of this system?"
11. "Can you identify any subsystems within the whole system? If so, describe one."
12. "Does this system require symmetry between any of its parts? If so, describe the symmetry."
13. "Describe how the functioning of this system would change if one of the parts wears out."
14. "If this system stops working, how would you go about fixing it?"
15. "Give an example of how this system might respond to a stimulus from outside itself."
16. "Give an example of how this system might respond to a stimulus from the environment outside the system."
17. "In what way is it useful to think of this item as a system?"
18. "Could someone develop a computer simulation of this system? Justify your answer."

Here are sample questions that could be asked of learners who are beginning to study systems by analyzing **a toy as a system**:

- "How does this part help the toy work?"
- "How did you figure out what this part does?"
- "If the part does not help the toy work, is there some other way in which it is important to the toy?"
- "Does this part affect other parts in any way?"
- "Could you put the parts of this toy together in a different way and still have the toy work as it does now? Explain your answer, using drawings if you wish."
- "Could you take away any part of this toy without changing the way the toy works? If so, which part?"

Here is an example of prompts that could be asked of learners who are studying **the bicycle as a system**:

- "Identify at least six parts of the bicycle. If you don't know the name of a part, make up a name. Tell what function each part has."
- "The seat is one part of the bicycle. Use three words or phrases to describe the seat. Do any of these words or phrases also describe the whole bicycle?"
- "Could any part of this bicycle be made of a different material and still help the bicycle carry out its function?"
- "Can any one part of the bicycle carry out the job of the whole bicycle? Explain your answer."
- "What parts of the bicycle must work together if you want to ride around a corner?"
- "Can you take a part from another bicycle and use it to replace a part in this bicycle and still have the bicycle carry out its function?"
- "Could some parts of the bicycle be arranged differently and the system still carry out its function? Explain your answer."
- "Can you identify any subsystems within the whole bicycle system? If so, describe one subsystem."
- "Does the bicycle require symmetry between any of its parts? If so, describe the symmetry."
- "What will happen to the bicycle if one part, such as a spoke, breaks? What if all the spokes break?"
- "Is it useful to think of a bicycle as a system? Justify your answer."

What Can I Do to Help Learners Improve in Applied Technology?

Any instructor can, when asked, recall learners who knew the subject matter extremely well but couldn't apply their knowledge to everyday life. Those learners could memorize information and recite it back without a problem; they got "As" on traditional paper-and-pencil tests. However, they couldn't use their knowledge to the solve problems they encountered at home, at work, or in their community. This type of learner grasps the **content**, but for one reason or another, doesn't have the **process skills** needed to apply that knowledge to the problem at hand. When planning instruction, it's important to consider both the content (e.g., the principles of electricity) that learners need to understand and the process skills (e.g., predicting, inferring) they need in order to successfully solve problems.

People who are engaged in problem solving need to be able to **understand systems, identify problems, determine and prioritize options, apply solutions, and determine the effectiveness of their actions**. For example, when a bicycle chain becomes disengaged, the person who fixes the bicycle (e.g., the rider, or the rider's parent or spouse) needs to understand how the chain contributes to the operation of the system. The repair person also needs to understand what went wrong, how it might be fixed, and once fixed, if the repair strategy was effective. (The list of questions in the previous section is really a list of questions that encourage learners to develop their process skills.)

When training learners to be effective problem solvers, instructors need to provide them with opportunities to develop and refine their process skills. The list of process skills, on the following page, includes definitions of those skills. You may wish to use it to identify the process skills you currently teach and the additional ones that you might need to help your learners develop or practice.

Process Skills Descriptions and Self-Check for Instructors

In the first column, check the process skills that you currently teach. In the second column, check the process skills that you feel you need to teach or help learners practice. Use this information as you choose activities from Targets for Learning.

I Teach	I Need to Teach	
○	○	**Observing**: Using the senses and extensions of the senses to examine or monitor the change of a system closely and intently; noticing and recording aspects that are not usually apparent on casual scrutiny.
○	○	**Communicating**: Conveying information, insights, explanations, results of observations or inferences, or measurement to others. This might include the use of verbal, pictorial, graphic, or symbolic modes of presentation.
○	○	**Comparing**: Relating one thing to another and observing similarities and differences.
○	○	**Ordering**: Using observed characteristics to organize objects or systems in a sequence. Options for solving problems often need to be ordered by the ease and cost of implementation and the likelihood that the action will result in a solution.
○	○	**Making models**: Constructing a representation of a system that is based on observations and inferences.
○	○	**Measuring**: Using instruments to make quantitative descriptions of objects or systems, either as compared with others or as compared with a standard. This includes the monitoring of changes in size, shape, position, and other properties.
○	○	**Recording**: Writing the observations that are made during experimentation.
○	○	**Interpreting data**: Translating data and summarizing the implications of the data in the context of a scientific investigation. Familiar language should be used to describe the significance or meaning of data and observations.
○	○	**Experimenting**: Gathering information to test a hypothesis.
○	○	**Predicting**: Forecasting a future observation or the next occurrence in a system or series of events based on prior observations and inferences.
○	○	**Hypothesizing**: Forming precise questions to be tested scientifically. Formal hypotheses are stated so that each explanation may be tested and, based upon the results of those tests, accepted or denied.
○	○	**Inferring**: Suggesting explanations, reasons, or causes for observed events.
○	○	**Categorizing or classifying**: Arranging objects or systems into categories based on shared characteristics.
○	○	**Recognizing relationships**: Interpreting interactions between different components of a system.
○	○	**Controlling variables**: Holding all variables constant except one whose influence is being investigated to evaluate changes in others.

Problem-Solving Strategies

Another thing that instructors can do to help learners develop skills needed for applied technology is to give them opportunities to **practice solving problems**. Problem-solving strategies are critical to any instruction aimed at improving all levels of applied technology skills. To be effective technological problem solvers, people need to be able to do the following:

- Understand cause-effect relationships (e.g., What parts of systems affect and are affected by other parts?)
- Make comparisons (e.g., What commonalities and differences do systems have?)
- Recognize probable outcomes (e.g., How will the system react to a specific action?)
- Predict what should happen next (e.g., Based on what has been observed, what is known about a specific system, and what is known about related scientific principles, make a prediction about what will happen next.)
- Judge spatial relationships (e.g., Visualize how a system operates and mentally rotate system parts to solve problems within a given system.)
- Notice what appears out of place (e.g., Observe a malfunctioning system in operation to determine what is not working correctly.)

The basic components of effective problem-solving strategies are—

- **Identifying the problem** (e.g., asking "What is the goal?" and "What limits does the goal impose?")
- **Analyzing and interpreting data** (e.g., reading a gauge, interpreting a printout). This includes identifying and disregarding nonessential data.
- **Exploring and evaluating solutions** (e.g., asking "What options are available?" and "Which option is best, taking into account many variables, including cost, time, human resources, materials, environment, and expertise?")

One well-known problem-solving model is the IDEAL* model. The IDEAL model was designed as an aid for teaching and improving problem-solving skills. The IDEAL process includes the following steps:

I = Identify the problem (e.g., determine what needs to be done).
D = Define and represent the problem (e.g., sharpen and clarify the boundaries).
E = Explore alternative approaches (e.g., analyze and evaluate alternatives).
A = Act on a plan (e.g., determine the logical steps to be used and how to progress through the steps).
L = Look at the result (e.g., determine whether or not the plan worked).

The practice problems in this book guide learners through the IDEAL problem-solving process.

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* *The IDEAL Problem Solver: A Guide for Improving Thinking, Learning, and Creativity* (1984).

The best way to help learners be effective problem solvers is to give them opportunities to develop and refine their problem-solving skills. The options for developing activities that promote problem solving are nearly endless. The following guidelines may be helpful:

- **Minimize instructions** so that learners are encouraged to invent innovative ways to accomplish their tasks.
- **Provide learners with a variety of materials** from which to choose.
- When learners have questions, the best response is to **repeat the beginning instructions, without giving further information**. This strategy encourages learners to figure out how to use the materials to reach their goal.
- **Allow plenty of time for learners to explore**. As long as learners are actively engaged, learning is taking place. In addition, when ample time is allowed, learners are able to do more in-depth investigation.
- **Encourage learners to share ideas with each other**. This strategy reflects how people solve problems in the workplace—with input from others. Most problem solving activities lend themselves to having learners work individually or in pairs. Occasionally, it is appropriate for learners to work in small groups of 3-5. When learners work individually, they should be encouraged to seek others' input. In addition, it is important to assign learners to work in both same-gender and mixed-gender groups.

The following activities will get you started. (Refer to the Resource lists in Appendix B, pp. 307-325, for books, kits, computer software, and Internet sites that describe additional strategies for helping learners develop and practice solving problems.)

CAUTION: Be sure to try each of these activities yourself before assigning them to learners.

Problem Solving Activity 1: Designing and Building

Build the Highest Tower

Challenge learners to build the highest tower they can by using nontraditional materials. For each pair of learners, provide 2 pieces of paper, 10 paper clips, and 1 pair of scissors. To measure and compare the height of towers, you can use a yardstick or measuring tape. Or, if you prefer, you can place a strip of masking tape vertically on a wall or doorjamb starting at the floor and extending about 5 feet; the names or initials of each learner pair can be written at the height attained by their tower.

Instructions for Learners

Give learners the following instructions (and no other information):

- Only the materials provided may be used to build the tower.
- The towers must be free standing; they may not lean against a wall or be held up.
- Towers must be brought to the tape on the wall for measuring (optional).

Measurement

Measure the height of each structure as it is finished. You may measure structures at the building site or you may wish to have learners bring their towers to the measuring site. On the tape at the measuring site, write the initials or names of the learners beside the height of their tower. When all towers have been measured, announce the winners.

Discussion

Have learners examine all of the towers. Encourage them to discuss the strategies that made some towers more successful than others.

Continuation

Allow time for experimentation by instructing each team to build a second tower. This time, give them 15 minutes to experiment with scratch paper before they actually begin their second construction.

Variation 1

Have learners build a structure as high as they can by using some or all of the following materials:

- As connectors, use miniature marshmallows, spice drops, modeling clay, and/or dried peas that have been soaked in water.
- As building materials, use uncooked spaghetti, toothpicks, plastic rods, and/or straws.

Variation 2

Using the fewest possible items, have learners work in pairs to design a bridge that will span the distance between the arms of a chair so that the center of the span will support a roll of toilet paper. Materials might include tongue depressors, pipe cleaners, plastic rods, paper clips, and/or straws.

Variation 3

Using no more than 25 building pieces (e.g., LEGOs®) have learners construct the tallest possible freestanding structure.

Variation 4

Using only newspaper, and no other materials or equipment, have learners construct the longest possible freestanding bridge.

Design a Flying Machine

Flight offers learners with many options for solving problems. The following activities are just the "tip of the iceberg"—there are many resources with more ideas. The *Sciencewise* books, which are described in the Resource section in Appendix B, p. 311, suggest over 30 design activities—including detailed instructions and learner worksheets.

Flight Activity 1

Challenge learners to make a single sheet of paper travel as far as possible. After paper airplanes are designed, allow plenty of time for learners to experiment by flying their airplanes (outdoors), modifying their designs, and retesting them.

Flight Activity 2

Provide learners with 3 or 4 different weights of paper (e.g., plain copy paper, 80-pound paper, card stock, construction paper). Have learners fold a traditional-style paper airplane from one piece of paper. Give each learner a paper clip to use as a rudder to improve the speed and height of the plane's flight. Allow plenty of time for exploration. Then facilitate a discussion during which learners develop generalizations about what factors helped and hindered flight effectiveness.

Some **questions** that you might use for Flight Activities 1 and 2 are—

- "What is the farthest that we could make a paper plane go?"
- "Why do some planes work better than others?"
- "Which kind of paper is better than others?"
- "Which designs work better than others?"

Problem Solving Activity 2: Building Things That Do Something

Inventions

Engagement Activity

Encourage creativity by having learners invent new uses for common items (e.g., brick, coat hanger, potato).

Machines and mechanical systems in the workplace and the home are really a combination of more than one simple machine. Learners can gain an understanding of how machines and mechanical systems work by designing and building them. Understanding how systems work is critical to understanding how to solve problems related to those systems. This activity's goal is to have learners work individually or in pairs to develop a machine that will do something.

Prerequisite Skills

Ideally, learners should understand how simple machines (e.g., levers, pulleys, gears, inclined planes, wheels and axles) work. However, learners can succeed at this activity without a background in simple machines.

Materials

It is best to provide learners with a wide variety of "recycled" and "junk" materials for this activity. Use the following list for ideas; add your own.

- balloons (several shapes)
- beads
- blocks
- brad nails
- buttons
- cardboard
- craft or popsicle sticks
- dry spaghetti
- egg cartons
- empty thread spools
- empty boxes (e.g., cereal)
- empty film cans
- feathers
- fishing line
- magnets
- metal or plastic pipes
- milk cartons
- miniature marshmallows
- modeling clay
- mousetraps
- old panty hose or nylons
- packaging peanuts
- paint stirrers
- paper bags (several sizes)
- paper clips
- paper plates
- paper towel and T.P. rolls
- parts of old machines
- plain paper
- plastic bottles
- plastic bag twist ties
- plastic lids
- potato slices
- rubber bands
- shoelaces
- small pieces of wood
- spice drops
- spring-type clothespins
- straws
- thin metal coat hangers
- thumbtacks
- tin cans (filed)
- Tinker Toys
- toothpicks
- unsharpened pencils
- various size washers
- yarn and string

Procedure

Have learners work in pairs to design and build a machine that *does* something. (You can have learners develop their own ideas or you may wish to have them choose from the list provided in this section.) Give learners the following instructions:

- Examine the materials that are available for you to use as parts for your machine.
- Draw your machine.
- Describe your machine in words. What does it do? How does it function? If working individually, share your description with a classmate.
- Name your machine (optional).
- Build your machine.
- Demonstrate how your machine works.

Role of the Instructor

If learners are stuck, you can help them discover for themselves how they might combine things to create their machine. Circulate around the room, observing learning and providing support for those who appear to be having a hard time coming up with ideas. Instructors might ask questions such as—

- "What will your machine do?"
- "How will it work?" In other words, how will the parts interact?
- "What materials will be required to build it?"

Some functions of machines that learners can create include the following:

- ✔ Pick up dirt from the floor
- ✔ Reach a paperclip on a high shelf
- ✔ Look around a corner
- ✔ Sort mixed beans and rice into separate piles
- ✔ Measure time
- ✔ Move a piece of paper across a room
- ✔ Lift an object without touching it
- ✔ Crack an egg
- ✔ Water a houseplant
- ✔ Toss dice
- ✔ Mash potatoes
- ✔ Turn pages in a book
- ✔ Trap a fly
- ✔ Catch a raw egg

Variation 1

Have learners work in pairs to build a maze that will take a marble from the top to the bottom of a shoe box in 30 seconds.

Variation 2

Have learners design and build a "contraption" that will move a marble from one place to another. It should have at least 3 moving parts.

Variation 3

Have learners design and build a moving vehicle that is powered by only air.

Variation 4

Have learners design, build, and demonstrate Rube Goldberg-type contraptions. (You may want to share Rube Goldberg comics and have them examine and play with the *Mousetrap* game. You may also suggest that they make their own Rube Goldberg cartoons.)

Variation 5

Have learners work in pairs or small groups to design, build, and demonstrate a Rube Goldberg-type device that solves a problem with a minimum of 6 mechanical actions and reactions. Problems can include anything that group members agree to; they might include bursting a balloon, lighting a candle, turning on a radio, watering a plant, or moving an object.

Questions that you can adapt to any of the invention activities include the following:

- "What did you learn about engineering from your efforts? What were your frustrations?
- Were you proud of your results?"
- "What energy transformations take place in your machine?"
- "Is your machine high in efficiency?"

Problem-Solving Activity 3: Black Boxes—Predicting What's in the Box

The following activities help learners develop many process skills, including prediction, observation, and inference.

Engagement Activity

Have learners guess how some machines that have hidden "works" (e.g., pencil sharpener, disposable camera, clock) operate. Have them draw what they think is inside. Have groups of learners take some broken machines apart to analyze how they work. (You may wish to use the list of questions that instructors ask learners as they analyze systems, pp. 19-21.)

Exploration Activity

Provide pairs of learners with a sealed box that contains several loose items. Have them determine what's inside by making guesses and then testing them out. Tell learners that you will answer questions only with "yes" or "no." Materials that might be used are metal washers or screws, straws, rubber balls, cotton balls, small beads, and coins—use your imagination.

Variation 1

Have learners complete the "Mysterious Pushrod Boxes" activity that is described in *Inventor's Workshop*, which is described in the Resource section, Appendix B, p. 321. In this activity, learners examine how pushrods move in a sealed box to determine, through prediction and experimentation, how the rods are connected. (Pushrods boxes can be constructed with dowels, paint stir sticks, or tagboard.)

Learners can then create their own pushrod boxes and have others try to determine how they are configured.

Variation 2

Have learners fix the rattle in The Rattle Box. Learners examine a black box that has a rattling sound coming from it when it is shaken. They make and test hypotheses for fixing the rattle. This process continues as learners are given more testing equipment that is comparable to advancements in technology and medicine (e.g., flashlight, magnet, probes, simulated X rays, and simulated ultrasound). Developed for grades 6-12, this kit can be ordered through William Sheridan & Associates, whose address is listed in the Resource section, Appendix B, p. 324.

Explanation

Facilitate a discussion during which learners can summarize what they learned from these activities. In addition, learners should have opportunities to ask questions, to investigate the topics about which they have questions, and to find the answers to their questions.

Extension

Have learners analyze broken toys and machines. Once they figure out how the broken items operate, have learners suggest ways to fix them. This may involve the use of tools and measurement equipment. If appropriate, have learners fix the items.

Gender Equity: What Can I Do?

There's another aspect of instruction that instructors need to consider when planning to help learners develop skills related to applied technology. Something that is often overlooked in math, science, and technology instruction is gender equity—providing instructional opportunities that will help **all** learners succeed. When it comes to applied technology, many females do not have the same types of experiences, both in and out of school, as males. As a result, males and females have traditionally received differing qualities of education—even when they study in the same classroom. It's possible that you are skeptical about this—especially if you are male. Please don't stop reading; there are some simple things that you can do to check it out for yourself.

Researchers[illegible] have found the following inequities in the way that male and female students are treated in school:

- From preschool to graduate school, **female students receive less teacher attention and less useful teacher feedback**.
    - ✔ Teachers call on female students less often than they call on male students.
    - ✔ Teachers ask probing and higher-order thinking questions of female student less often than they do of male students.
    - ✔ Teachers often instruct male students on how to perform tasks but tend to *do* tasks for female students.
    - ✔ Teachers tend to give female students less feedback (e.g., praise, criticism) than they do male students.
- In class, **female students talk significantly less than males students do**.
    - ✔ In elementary and secondary school, female students are eight times less likely to call out comments. When they do, they are often reminded to raise their hands, while similar behavior by boys is accepted.
    - ✔ Female students are less likely to raise their hands. Reasons for this are that they are aware that males get called on more, they may take longer than males to think about their responses before raising their hands, and they may not have confidence in their ability to answer correctly.
- When working in coed pairs, males tend to dominate in math, science, and technology-related activities, which results in females having fewer opportunities to do hands-on learning.
- Female students rarely see mention of the contributions of women in the curriculum. Most textbooks continue to report male worlds and have pictures of males actively doing things while females passively watch and support them.

[illegible] The most comprehensive research on the topic of gender equity has been done by Myra and David Sadker. Their findings are published in ***Failing at Fairness: How America's Schools Cheat Girls*** (1994).

- Females experience pressure from their friends to *not* do well in science, math, and technology-related classes; they may be teased for being "nerdy" or unfeminine if they try to do well.

Outside the classroom, most females have not received opportunities to work with tools or mechanical systems. Females don't have as many toys that encourage them to build, explore, or tinker. For example, females do not generally build with LEGOs® or fix their own bicycles. And as in school, adults tend to *instruct* males on how to perform tasks but tend to *do* tasks for females. As a result, many female learners do not have the foundational skills that are needed to succeed in applied technology.

This subconscious inequity has far-reaching consequences. Because females have had fewer opportunities to develop "mechanical" skills, they are often less prepared for and less likely to take courses in math, science, and technology. In addition, it is clear from the research that those females who do take upper-level math and science courses are also treated very differently than their male classmates; many stop taking them. Taking fewer of these courses has resulted in fewer high-paying occupational options for female workers.

What can instructor do to help female and male learners have equal chances to succeed with applied technology? The following list is meant to provide you with some ideas.

1. The most important thing that you can do, as a male or female instructor, is to **be aware of your subconscious bias** and to accept that virtually everyone has been socialized to have that bias. (If you don't believe that you treat male and female learners differently, ask a colleague to observe you in the classroom or make a video tape of your teaching or training to determine whether or not you provide female learners with less attention and different expectations than you do male learners.)
2. Make a conscious effort to **provide female and male learners with equal amounts of attention.**
3. **Create an atmosphere that fosters female learners' participation.** Because females are generally more shy than males about speaking in public, you can make it more likely that females will express themselves by making small changes in your own behavior. For example, when asking questions in coed settings, make a conscious effort to wait 5-10 seconds before calling on anyone. You'll be surprised at the number of timid hands that go up in those few seconds. Or, if only 1/3 of the learners have their hands up after you ask a question, you might want to say, "Think about it and talk with the person sitting next to you. I'll ask again in a few minutes."
4. **Pay attention to group dynamics**—who speaks, how often, for how long, in what order, and who interrupts whom. Since females tend to speak less often and for shorter periods of time, be sure to acknowledge their contributions.
5. **Don't "teach down" to any learners.** Expect equally high performances from males and females and of people of all races and national origins (e.g., don't assume that a female learner can't use tools or analyze complicated systems).

6. **Involve female learners in construction and manipulation of equipment and use of tools.** They may not have had these types of experiences in the past. For example, many females have not had opportunities to use pliers, pipe wrenches, handsaws, electric drills, ratchet sets, ohmmeters, micrometers, gauges, or bench vises. Instructors should provide opportunities for them to learn these skills.
7. **Provide female learners with additional instruction or practice, when needed.**
8. **Use a collaborative, cooperative approach to activities** rather than a competitive one.
9. **Use interactive methods**; have learners do some of their work in small groups. Females tend to be more effective when they can share their ideas with other.
10. To prevent males from dominating activities in which they have skill and experience, **pair females with females and males with males** some of the time.
11. **Foster females' independence.** Hold them accountable when they engage in "learned helpless" behavior. When they say "I can't do it" before exerting effort, find ways to re-engage them in the activity. Show faith in their abilities to do things for themselves.
12. **Use more than one method of assessing learners' achievement.** For instance, do assessments using multiple-choice tests and model building (at which males tend to perform better) as well as essay tests, projects, and reports (at which females tend to perform better). Refer to the Assessment section, pp. 45-52, for additional options.

Where Do I Begin?

So here you are: interested in using Targets for Learning as a resource for helping learners develop and/or practice problem-solving skills with technology and wondering where to begin. Unfortunately, that's not an easy question. Everyone using this book has a unique blend of experience, ideas, resources, and needs. Consequently, the following list, which was developed by instructors who piloted these materials, is meant to give you different ideas about how you might use Targets.

1. **Help learners attain the overall goal of applied technology instruction**, which is to instill—
   - A general understanding of how machines and mechanical systems work, particularly those that are commonly found in service, retail, and manufacturing businesses
   - Problem-solving skills and basic knowledge of technical procedures for solving technological problems in the workplace
   - Confidence in their abilities to solve technological problems
2. **Learn about Work Keys skill levels.** By teaching yourself about the skills required to solve increasingly complex problems in the workplace, you will gain insights into how to help learners gain those skills. (Refer to pp. 3-8 for additional information about Work Keys and what the skill levels signify.)
3. If possible, **begin by determining each learner's current applied technology skill level with a pretest**. (Refer to the Assessment section, pp. 45-52, for detailed information about using Work Keys and informal assessments to determine skill levels.)
4. Based upon pretest results, **decide what skill level(s) you will begin instruction with**. Some options follow.
   - Begin by working with Level 3 and below Level 3 learners. Once they have increased their skill levels, work with all learners who originally pretested at Level 3 and those who scored at Level 4. As they improve their skills at problem solving with technology, group them with the Level 5 learners and continue the process until all learners are solving Level 6 problems.
   - Work with two level-based groups at the same time: (1) below-Level 3 and Level 3 learners and (2) Level 5 learners. Once Level 3 learners have raised their skill levels, group them with Level 4 learners and give them opportunities to solve moderately difficult technological problems. Once Level 5 learners have raised their skill levels, group them with Level 6 learners and give them opportunities to solve complex technological problems.
   - Work with all learners at the same time, starting by teaching with Level 3 activities and problems and moving toward Level 6 activities and problems.

5. **Compare your existing curriculum with the proficiency outcomes** listed in Appendix D, pp. 333-335. Look for—
   - **Gaps in content** (e.g., identify scientific and technological principles that you are not teaching, but should be teaching
   - **Gaps in process skills** (e.g., identify process skills that you are not teaching and/or reinforcing, but should be)
6. Read through Targets for Learning materials and **choose a topic to begin with**.
7. **Familiarize yourself with the content involved in the problem.** Each problem contains a brief description of the scientific principles involved in solving the problem. In addition, there is a list of Basic Scientific Principles in Appendix C, pp. 327-331. You may also wish to consult outside resources; those listed in the Resource section, pp. 307-325, may be of help.
8. For the activities that you have chosen to begin with, **decide if you want to separate learners into level-based groups**. Grouping may help you customize instruction to meet learners' needs. During the pilot study of this book, some instructors separated learners by Work Keys level. Others worked with all learners together. A few decided that it would be best to have learners work in a variety of structures that changed for each learning activity; their learners solved applied technology problems in level-based groups, mixed-level groups, and individually.
9. **Plan to employ instructional strategies** that help learners develop effective problem-solving skills, including the following:
   - **Model** problem-solving strategies—explain your rationale for making decisions while solving problems.
   - Provide **frequent and varied hands-on practice**, in an atmosphere that fosters curiosity.
   - Use the strategy of **scaffolding**—providing learners with some type of physical support (e.g., diagrams, outlines).
   - Use the strategy of **fading**—gradually withdrawing instructor support to encourage learner independence.
   - Use the strategy of **coaching**—asking specific questions and making suggestions to guide the development of learners' skills. (Refer to the list of questions that promote inquiry, pp. 17-18.)
   - Provide opportunities for learners to **solve problems cooperatively** (e.g., to work individually but share ideas with classmates, to work in assigned pairs, and to work in assigned small groups).
   - Have learners work on some tasks individually, some in pairs, and some in small groups of 3-5 learners.

Dividing learners into groups requires some thought and planning. Depending on your goals, the activity, and your learners, it may be appropriate to assign learners to work in pairs or small groups based on the following characteristics:

- similar-ability groups (e.g., have Level 4 learners work together)
- mixed-ability groups (e.g., have Level 3, 4, and 5 learners work together)
- same-gender groups (e.g., females work together, males work together)
- mixed-gender groups (e.g., males and females work together)
- similar-motivational groups (e.g., have highly motivated learners work together; have less motivated learners work together)
- mixed-motivational groups (e.g., have highly motivated learners work with unmotivated learners)

It is important to use different groupings for different activities; do not have the same learners work together all of the time. After all, successful workplace problem solving involves working in a variety of teams.

How Should I Structure Learning Activities?

If you've completed the steps described in the preceding "Where Do I Begin?" section, you're on your way. Here are some suggestions for helping learners develop their applied technology problem-solving skills by using Targets for Learning.

1. **Help learners understand *why* it is important to be an effective problem solver with technology.** Discussions about how technology is used in their lives (at school, home, and work) will help learners understand for themselves the relevance of applied technology.
2. **Teach learners about the Work Keys levels.** When learners understand how the level of difficulty of applied technology problems is determined, they are more likely to understand
   - Their current problem-solving skill levels
   - What they need to do to improve their skills

   (Refer to the overview of Work Keys, pp. 5-8, for further information.)
3. **Conduct the learning activities described in Targets for Learning.** Instruction is most effective when learners participate in the Targets *learning activities* **before** working on the Targets *problems.*

REMEMBER: Your goal is to help learners apply their understanding of basic technological principles to a solve a wide variety of problems. You can do this by making sure learners—

- Understand the basic scientific and technological principles involved in work place problems
- Know how to solve problems (using the IDEAL model or another similar model)

46

To help learners gain an understanding of the basic principles of technology and problem solving, structure inquiry-based learning opportunities that follow the Five Es of Instruction format—and more. The Five Es are described in detail on pp. 14-16.

- Introduce a new concept to learners with an **engagement** activity (optional).
- Begin by providing **exploration** activities for learners.
- Then, help learners **explain** what they learned during exploration.
- **Evaluate** learners to make sure that they understand the concepts being taught.
- Provide learners with opportunities to **extend** their learning to other applications of the concept and skills that have been learned.
- Have learners work individually, in pairs, small groups, or as a class to **solve the related practice problem.**
- If learners have worked alone or with a few others, **review** the problem with the whole class.

NOTE: To encourage learners to work through the IDEAL model in a step-by-step manner, instructors should have them **read and answer one question at a time**. This can be done easily if problems are placed on overhead transparencies so that questions can be uncovered one at a time.

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4. **Supplement Targets materials** with other science resources as needed. Targets for Learning is not meant to be a comprehensive science resource. (The Resources section, Appendix B, pp. 307-325, suggests additional hands-on science activities and materials that inform instructors about the basic scientific principles that are encountered when solving technology-related problems.)
5. **Provide learners with additional workplace problems** that involve similar scientific principles or require learners to employ similar problem-solving strategies. It may be appropriate for learners to develop their own problems, which classmates can then solve.
6. **Use various strategies for assessing improvements** in applied technology skills that learners have attained. (Refer to the upcoming Assessment section, pp.45-52, for some suggestions.)
7. Plan **additional interventions** for learners whose skills did not improve as much as needed.

The following excerpts from the logs of several of the instructors who piloted *Targets for Learning: Applied Technology* may give you insights into planning how to use the materials:

> *"Peer-assisted learning was extremely successful in our eight-week program for multilevel women. Higher-level learners, who were paired or in small groups with lower-level learners, aided the others."*
>
> Martha Blowers, ONOW Instructor

> *"It was important for us to blend this "new" Targets for Learning material with the materials that we already use."*
>
> Carol Higgins, ONOW Coordinator

> *"My applied science for welding class consisted of juniors from various schools, with greatly differing science backgrounds. Their academic levels also spanned a broad spectrum. In addition, the students were not an overly motivated group of people. I knew that my students would probably lose interest if I suddenly changed gears and began hammering away on applied technology. I had to ease them into it—so I decided to use Fridays as our instructional days.*
>
> *"First, I needed to find a way to motivate them to participate in these activities. To accomplish this, I began by explaining how Work Keys tests are being used by more and more local employers and that the skills measured by Work Keys are important to success on the job. I then asked 'What do you think employers look for in a potential employee?' After a few answers, someone brought up the idea of needing to be a good problem solver. We continued by talking about how technology has become a huge part of just about* **all** *work environments. I then gave the students a Level 4 problem and asked them to solve it. I gave them no guidance whatsoever. Very quickly I heard grumbling about their not knowing "this stuff." That concluded our first day. I had a bunch of frustrated students. Now it was time to begin the work.*
>
> *"The following Friday, I asked if anyone had figured out the Work Keys problem from the past week. For the most part, I was told that they had no understanding of the particular system in question. We then continued our discussion about technology in the workplace. The students began to understand that technology is always changing and that there is no way that a person could be taught* **everything** *about it. They started to see that workers have to be able to solve problems by drawing on past knowledge and making good, informed guesses about adapting it to the present situation. I told the students that just as there are steps to setting up various welding equipment they use there are steps to use when solving problems. I introduced the IDEAL model that is described in* Targets for Learning: Applied Technology. *I went over what each letter stood for and told the students that they needed to commit this information to memory.*

"Our next Friday session began with a quiz over the steps of the IDEAL decision-making model. I didn't collect the quizzes as most students had forgotten a few of the letters. (I gave those who got it right some extra-credit points.) I then presented a very simple problem from Targets for Learning—going through it step by step using IDEAL. The students wanted to skip steps and jump ahead, but I made them slow down and look at each step.

"Each Friday for the next ten weeks, we continued our problem-solving practice. We would do a few Targets problems together, and then the students would work on a few in small groups and finally on their own. We also did some of the hands-on activities included in Targets. Due to limitations of time and resources, I couldn't always provide lab activities for students. So I sometimes did demonstrations—or had students do demonstrations—for the class. We followed the materials through from Level 3 to Level 6 as the weeks progressed.

"When my students took the Work Keys posttest, most of them took it seriously. After the test, most said that they felt more comfortable taking it this time. I think it had to do with the fact that they now realized applied technology covers a broad range of topics—many of which are not familiar to them. Their knowledge of the problem-solving process, however, gave them a place to begin analyzing each problem and allowed them to move forward in an educated manner."

John Jarvis, Applied Technology Teacher

Assessment

"Assessment" means different things to different people. To some, assessment means traditional paper-and-pencil tests. To others, assessment means finding alternative ways to determine what learning has taken place. This latter meaning has sometimes been called "alternative assessment," "authentic assessment," or "performance-based assessment." Because Targets for Learning is about solving authentic problems, this second type of assessment is preferred to traditional methods. The following options may help you choose which assessment methods will be most appropriate for you and your learners.

Assessments To Use Before and After Targets for Learning Instruction

Assess the gains made by learners from the time they began using Targets for Learning until they completed using Targets. These summative gains are best documented by using a pretest-posttest strategy. There are many options, including the following:

- **Assign an open-ended problem for learners to solve** (e.g., one of the problems described on pp. 26-32). Observe learners solving the problem.

  ✔ For each learner, complete a checklist that includes the process skills and relevant content-area knowledge. You can develop your own checklist or use the one provided on pp. 45-51, in this section. If you are not able to keep such a detailed checklist for each learner, consider using the summary sheet provided on p. 52.

  ✔ It may also be appropriate to have learners complete a report that asks about the content and the process skills that they used to solve the problem.

  If you're not sure where to start, refer to books such as *Science Process Skills: Assessing Hands-on Student Performance*, which is listed in the Resource section, p. 308.

- **Give learners the Work Keys applied technology test** at both the beginning and the end of instruction. This test, which is administered at all of Ohio's vocational schools and adult full-service centers, is an accurate way for learners as well as instructors to know the learners' pre- and post-instructional Work Keys levels. Before testing learners, teach them about effective test-taking strategies. You may wish to cover the following points:

  ✔ Read the instructions carefully. Make sure you understand the directions.

  ✔ Start at the beginning. Work Keys tests start with easier problems and progress to more difficult ones. So, you must get the beginning problems correct in order to get credit for the more difficult problems. For example, you must answer 80% of Level 3 questions before you can attain Level 4.

  ✔ When you read a question, underline key words and cross out unnecessary information.

- ✔ When analyzing questions, think through the steps in the decision-making process (i.e., IDEAL).
- ✔ If you have trouble answering a question, try to remember solutions to similar problems.
- ✔ Take things one at a time, using what you know and what you are told in the problem. Often, solving the problem involves combining a series of simple skills.
- ✔ Use the available space in the test book for scratch work. You are not expected to do all of the reasoning in your head.
- ✔ Draw diagrams that represent the words in the problems.
- ✔ To save time, use your calculator when calculations are required. Then check your answer for accuracy by estimating the correct answer (i.e., doing the calculation in your head).
- ✔ Eliminate one or more answers that you know are wrong. Cross them out so that you can clearly see the choices that are left.
- ✔ Make a best guess for problems you can't work out. (There is no penalty for guessing.) But guess **only** after you have—
  - Tried your best to answer a question
  - Eliminated answers that you know are wrong

- **Give learners a problem to solve at each Work Keys level.** The problems can be taken from *Targets for Learning: Applied Technology, ACT's Targets for Instruction*, or a real situation in your school or community. Although this assessment is not as comprehensive as giving the whole Work Keys test, this type of test will help you estimate your learners' skill levels.

- Use this space to add your own ideas about pretesting and posttesting.

Assessments That Check Learning and Provide Feedback

Determine what learners know through smaller, formative assessments. The following options may be helpful as you think about ways to document what has been learned about individual topics.

- **Allow learners to give input on how they will be graded.** By having learners help set grading criteria, the instructor is providing learners with opportunities to understand the objectives of the learning activities and to see the connections between what is learned and the way that learning is assessed.
- When you want to know how well learners understand specific content or process skills **before** beginning a specific section in Targets for Learning, give learners a brief (5-8 item) **quiz**. This will help you decide where to begin instruction.
- **Observe learners as they participate in Targets activities.** Jot down notes about the skills learners used and the improvements they have made.
- **Collect and grade a few of the problems** from Targets for Learning. As a check to see if individual learners are able to solve problems in applied technology, collect and grade several of the problems. Grading of all Targets problems is not recommended because the problems are meant to be a learning tool rather than an assessment tool.
- **Assign one-minute papers.** During the last few minutes of the class, ask learners to do two things: (1) summarize what they learned that day and (2) list any questions that they have about the day's materials. Writing one-minute papers helps learners take responsibility for their own learning, become skilled at synthesizing information, and practice writing. In addition, this is a good strategy for instructors to use to determine whether or not learners have attained the day's (or lesson's) objectives. Many instructors assign one-minute papers at least once weekly.
- **Assign individual journals** that describe what the learner did, how it worked, and how he or she felt about the problem-solving experiences. This self-reflection helps learners gain insights into how they learn and how they might learn better.
- **Assign self-critiques or reflections.** This is similar to the journal-writing assignment, but is written for a single lesson or problem. The learner provides a written account of what he or she did, how it worked, and how he or she felt about solving a specific problem. The aim of this assignment is to have learners consider what they might do differently when solving problems in the future.

- **Have individual learners build a model.** Sometimes the best way to tell if learners understand how a system works is to have them build a model that represents that system. Learners can also write a report (or make an oral presentation) that describes the system, provides a rationale for design decisions that were made, and presents options for solving problems that might occur if the system breaks down.

- Use this space to **write your own ideas** for assessing learners as they learn and practice skills related to technological problem solving.

Checklist of Learner's Process Skills and Content-Area Knowledge

Learner's Name ______________________________

Check one:

○ Preinstructional Observation ○ Postinstructional Observation ○ Other __________

Process Skills

Check the box in the column that represents the learner's ability to use process skills. Check first column (CN) if the learner can not perform this process skill. Check the second column (WA) if the learner can perform the given process skill with assistance. Check the third column (IN) if the learner can perform the given process skill independently. Use the space at the right to record specific information about your observations.

CN	WA	IN	
○	○	○	**Observing:** Using the senses and extensions of the senses to examine or monitor the change of a system closely and intently; noticing and recording aspects that are not usually apparent on casual scrutiny.
○	○	○	**Communicating:** Conveying information, insights, explanations, results of observations or inferences, or measurement to others. This might include the use of verbal, pictorial, graphic, or symbolic modes of presentation.
○	○	○	**Comparing:** Relating one thing to another and observing similarities and differences.
○	○	○	**Ordering:** Using observed characteristics to organize objects or systems in a sequence. Options for solving problems often need to be ordered by the ease and cost of implementation and the likelihood that the action will result in a solution.
○	○	○	**Making models:** Constructing a representation of a system that is based on observations and inferences.
○	○	○	**Measuring:** Using instruments to make quantitative descriptions of objects or systems either as compared with others or as compared with a standard. This includes the monitoring of changes in size, shape, position, and other properties.
○	○	○	**Recording:** Writing the observations that are made during experimentation.
○	○	○	**Interpreting data:** Translating data and summarizing the implications of the data in the context of a scientific investigation. Familiar language should be used to describe the significance or meaning of data and observations.

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CN WA IN

○ ○ ○ **Experimenting:** Gathering information to test a hypothesis.

○ ○ ○ **Predicting:** Forecasting a future observation or the next occurrence in a system or series of events based on prior observations and inferences.

○ ○ ○ **Hypothesizing:** Forming precise questions to be tested scientifically. Formal hypotheses are stated so that each explanation may be tested and, based upon the results of those tests, accepted or denied.

○ ○ ○ **Inferring:** Suggesting explanations, reasons, or causes for observed events.

○ ○ ○ **Categorizing or classifying:** Arranging objects or systems into categories based on shared characteristics.

○ ○ ○ **Recognizing relationships:** Interpreting interactions between different components of a system.

○ ○ ○ **Controlling variables:** Holding all variables constant except one whose influence is being investigated to evaluate changes in others.

Content

In the space below, write the specific scientific or technological principles that are being assessed. As you observe the learner, rate his or her ability to apply knowledge of specific content to a problem-solving situation. Check "CN" if the learner can not apply content to solve problems. Check "WA" if the learner can apply content to solve problems with assistance. Check "IN" if the learner can apply content to solve problems independently. Use the space at the right to record specific comments about your observations.

CN WA IN

○ ○ ○ Content: ______________________________

○ ○ ○ Content: ______________________________

○ ○ ○ Content: ______________________________

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Observations and Comments

Use the space below to make note of other things you observed about the learner's problem-solving skills and strategies.

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Summary Sheet of Learners' Process Skills and Content-Area Knowledge

Write each learner's name in the column on the left. Write the process skills and content-area knowledge that learners should be able to apply to solving technological problems across the top row. Indicate the degree to which each learner can use the process and content skills to solve problems by making the following notations:

CN = learner can not apply content to solve problems

WA = learner can apply content with assistance

IN = learner can apply content to solve problems independently

Learner's Name									

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APPLIED TECHNOLOGY

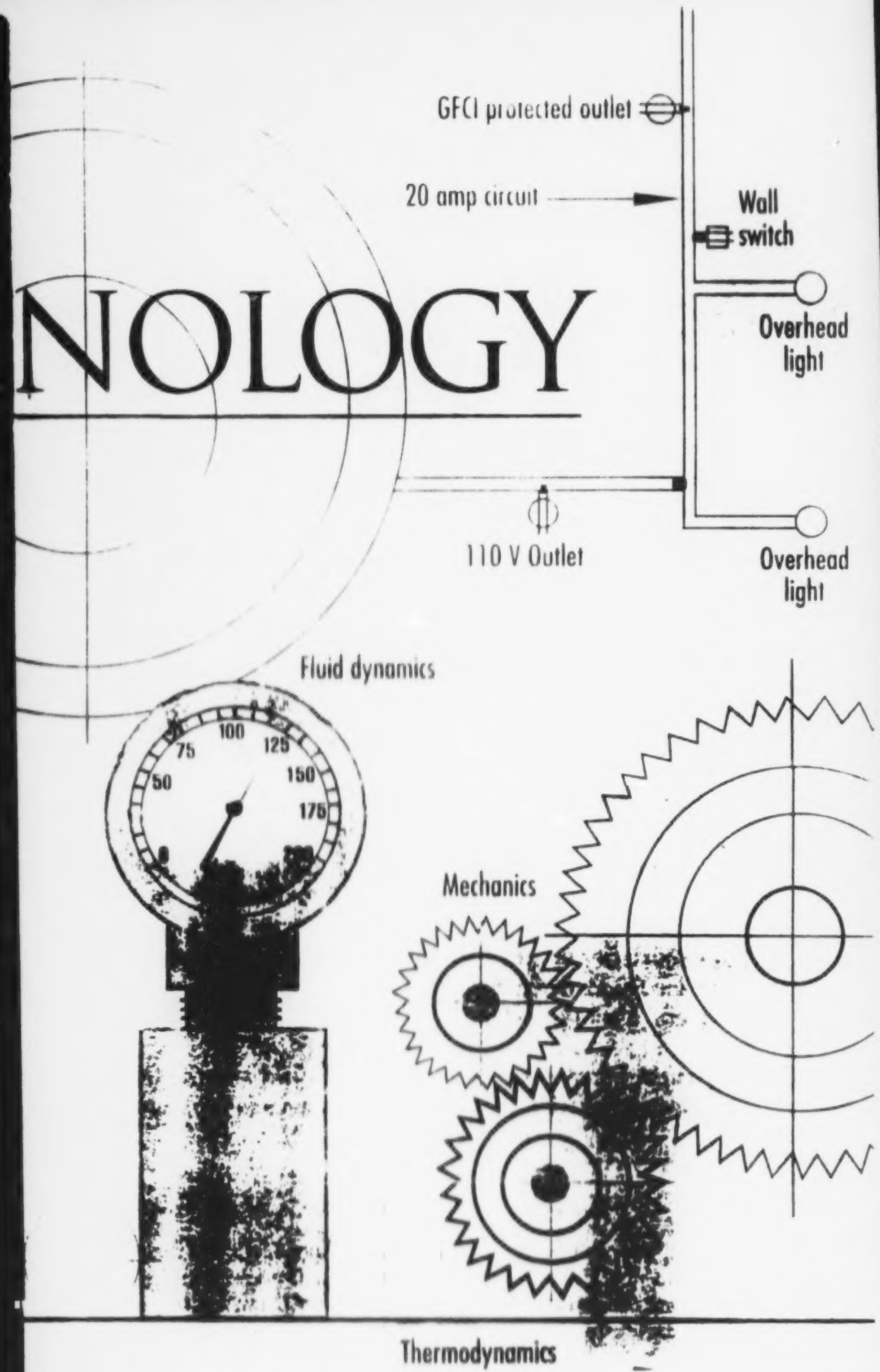
TARGETS FOR LEARNING

LEVEL 3 LEARNING ACTIVITIES AND PROBLEMS

The learning activities and problems in this section are designed to help learners improve to "applied technology Level 3.

"The questions were almost like puzzles to them—it was something they enjoyed doing."

Pilot Instructor


GFCI protected outlet
20 amp circuit
Wall switch
Overhead light
110 V Outlet
Overhead light
Fluid dynamics
100
75
125
50
150
175
Mechanics
Thermodynamics

BEST COPY AVAILABLE

Improving to Level 3

As defined and measured by Work Keys, Level 3 learners can

1. Apply elementary physical principles underlying the operation of technological systems (mechanics, electricity, fluid dynamics, and thermodynamics) to solve problems within those systems
2. Understand the operation of basic hand tools and simple electrical tools, subsystems of basic machines, and uncomplicated systems
3. Recognize obvious symptoms when diagnosing a problem
4. Determine, with efficiency and logic, what to check first when faced with a malfunctioning system or machine that contains 2-5 components that are potential sources of the problem
5. Select appropriate methods or materials needed to solve problems that involve a one-step solution or solution path

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The learning activities and problems in this section are designed to help learners improve to applied technology Level 3. In addition to presenting these, instructors may wish to use some of the books, software, and materials described in the Resource section, Appendix B, pp. 307-325, to—

- Gain a clearer understanding of the basic scientific principles involved in applied technology problems
- Select activities to supplement those included in Targets for Learning
- Recommend resources to learners wishing to gain deeper insights about the basic scientific principles involved in applied technology problems

Improving to Level 3 Index

Problem Number	Category	Problem Topic	Page Number
3.1	Thermodynamics	Driveway Resurfacing	57
3.2	Fluid Dynamics	Machine Shop Oil Drum	63
3.3	Fluid Dynamics	Water Tanks	71
3.4	Fluid Dynamics	Workstation Lubricator	77
3.5	Fluid Dynamics	Dust Collector	83
3.6	Electricity	Hair Dryer	89
3.7	Electricity	Wonderware Computer	95
3.8	Mechanics	Overheating Car	101
3.9	Mechanics	Clock Gears	109

Thermodynamics Problem 3.1: Driveway Resurfacing

Scientific Principle

Surfaces of different colors absorb heat differently; darker surfaces absorb more heat than lighter surfaces, and rough or dull surfaces absorb more heat than smooth or shiny surfaces.

Background

The color of a surface will determine the amount of heat it absorbs. For example, if the surface of a parking lot is dark, snow and ice will melt off more quickly than if the surface is light in color. The same principle holds true for other different-colored surfaces, including roofing shingles. Following the learning activities in this section, learners gain first-hand experience with this principle by making their own predictions and observations and by drawing their own conclusions.

Key Process Skills

(Refer to p. 24 for a description of each process skill.)

●	Observing
●	Communicating
●	Comparing
○	Ordering
○	Making models
●	Measuring
●	Recording
○	Interpreting data
●	Experimenting
●	Predicting
○	Hypothesizing
●	Inferring
●	Categorizing or classifying
●	Recognizing relationships
●	Controlling variables

Ohio Science Proficiency Outcomes

(Refer to Appendix D, pp. 335-337, for a description of each outcome.)

6th Grade	9th Grade	12th Grade
1 ●	1 ●	1 ●
2 ○	2 ●	3 ○
3 ●	3 ●	4 ●
4 ○	4 ●	5 ○
5 ●	8 ○	8 ○
6 ○	9 ○	12 ○
7 ○	10 ○	
8 ●	11 ○	
9 ●	12 ●	
10 ●	17 ○	
	19 ○	

Vocabulary

Heat
Absorption

Learning Activity

Level 3 problems directly state a problem or issue. Once the learner can identify the problem as stated in the question, solving it is a matter of understanding the concept of heat absorption by different-colored surfaces. To help learners understand this concept, have them participate in the learning activities that are described below.

Materials for Each Group of Learners

3 aluminum pie pans
Spray paint (black, white, and gray)
Measuring cup or graduated cylinder for measuring water
Freezer

Procedure

1. Have learners follow the procedure described on the following Worksheet.
2. Discuss the answers to the questions on the Worksheet.
3. Lead a discussion about other ways in which people encounter this principle in action.

Extensions

One way to cut maintenance costs could be reducing salt used on surfaces. Direct learners who have solved Problem 3.1 to do one or both of the following:

- Identify the effects of salt on different surface materials that are found both outdoors and indoors.

- Estimate and calculate the cost of the salt that would be used in the winter for different-colored surfaces.

Thermodynamics Problem 3.1 Worksheet

Problem

Do all colors absorb solar heat equally well?

Procedure

1. Spray the inside of each pie pan with a different color of spray paint.
2. When the paint is dry, add equal amounts of water to each pan.
3. Place the pans in a freezer.
4. After the water freezes, place the pans in a sunny location.
5. Predict which pan of ice will melt first. Circle your prediction: gray, white, black.
6. Check the pans throughout the day and record your observations below. Include the time and the amount of melting that has occurred in each pan.

Observations

Time	Black Pan	White Pan	Gray Pan

Questions

1. In which color of pan did the ice melt most quickly?
2. Why was it important to have the same amount of water in each pan?
3. What heated the pans?
4. Which pan most resembles the color of blacktop?
5. Which pan most resembles the color of concrete?

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Problem

A manufacturing company is planning to resurface an entrance driveway. The maintenance department says it will be more cost-effective to use a surface that encourages snow to melt by itself instead of requiring salt to melt the snow. Your job is to recommend the best-colored resurfacing material for the company to use.

Identify the Problem

1. What is the problem facing the company?
   - A. The company wants to save money by using a material that uses solar heat to melt snow.
   - B. There is too much snow in the winter where the company is located.
   - C. Snow piles up on the roofs of buildings.
   - D. The driveway has too steep of a slope.

Define the Problem

2. To begin to solve the problem, you should
   - A. See how fast salt will melt snow.
   - B. Find the average snowfall of the area in the winter.
   - C. Test which materials best absorb heat.
   - D. Find the average daily temperature during the winter months.

Explore Alternatives

3. Devise a plan to determine which surfaces absorb the most heat.

   A. Test different **masses** of the same material to determine which melts the most ice when using the sun's energy as the heat source.

   B. Test **colors** that are close to the colors of the surfaces to determine which melts the most ice when using the sun's energy as a heat source.

   C. Test different **surface areas** of the same color to determine which melts the most ice when using the sun's energy as the heat source.

   D. Test the same mass of different **materials** to determine which melts the most ice when using the sun's energy as the heat source.

Act on a Plan

4. You spray paint three 9″ aluminum pie pans black, gray, and white respectively. You then put an equal amount of ice in each pan. You place the pans in sun. Which ice will melt first?

   A. The black pan melts first.

   B. The white pan melts first.

   C. The gray pan melts first.

   D. The ice will melt equally in all three pans.

   E. The ice will not melt in any of the pans.

Look at the Result

5. Based on what you learned, which surface would be the best choice for resurfacing your company's entrance driveway?

   A. Concrete

   B. Blacktop

   C. Red bricks

Answers

1. A
2. C
3. B
4. A
5. B

Instructor's Notes:

Instructional Support Materials

Fluid dynamics

Fluid Dynamics Problem 3.2: Machine Shop Oil Drum

Scientific Principle

The relationship between fluid depth and pressure; as fluid depth increases, the fluid pressure increases. Whether holding back an ocean full of water or a gallon of water, the pressure exerted at the same depth is equal. *It is the depth of the liquid—not the amount—that determines fluid pressure.*

Background

Learners need to understand how to evaluate a situation, look at possible alternatives, and take the best action to solve a problem. By conducting the following activities, learners can practice solving Level 3 problems that relate to the effect of fluid depth and pressure.

Key Process Skills

(Refer to p. 24 for a description of each process skill.)

●	Observing
●	Communicating
●	Comparing
○	Ordering
○	Making models
○	Measuring
○	Recording
○	Interpreting data
●	Experimenting
●	Predicting
○	Hypothesizing
○	Inferring
○	Categorizing or classifying
●	Recognizing relationships
○	Controlling variables

Ohio Science Proficiency Outcomes

(Refer to Appendix D, pp. 335-337, for a description of each outcome.)

6th Grade	9th Grade	12th Grade
1 ●	1 ●	1 ○
2 ○	2 ●	3 ●
3 ●	3 ●	4 ○
4 ○	4 ●	5 ○
5 ●	8 ○	8 ○
6 ○	9 ●	12 ○
7 ●	10 ○	
8 ○	11 ○	
9 ○	12 ○	
10 ●	17 ○	
	19 ○	

Vocabulary

Fluid
Pressure
Pressurized
Reservoir
Puncture

Instructors can help learners understand how to solve problems similar to Problem 3.2 by offering some or all of the learning activities described below.

Learning Activity 1

Conduct a lesson that gives learners opportunities to **make choices**. It is helpful to show learners how to **rank** choices from least effective to most effective, since in many multiple-choice scenarios, more than one choice could be correct. For example, give learners the following choices for putting out a grease fire on the grassy area beside a gas grill:

A. Hope a big wind comes to blow it out.
B. Use a fire extinguisher.
C. Hope for rain.
D. Use a hose.

Although all four choices would work, the instructor could help learners see that choice C is the least effective, while choice B is the most effective and the most likely to be used. In addition, learners might think of and discuss the strengths and weaknesses of other choices (e.g., beat it out with a pine branch, throw a blanket over it, throw baking soda on it).

Learning Activity 2

Lead a demonstration concerning pressure in fluid dynamics so that learners see and understand that the pressure is greatest at the lowest depth. Whether one is trying to hold back an ocean full of water or a swimming pool of water really does not matter. The pressure will be greater if the hole in the swimming pool is eight feet deep as compared to a hole at a three-inch-deep level of the ocean.

Learning Activity 3

Conduct a discussion about divers who working at airplane crash sites. Ask learners to explain why they need to wear special pressurized suits to swim down to great depths.

Learning Activity 4

To show learners how to best make a choice and develop a plan, have them participate in the following learning activity, which illustrates the relationship between the properties of fluids and fluid depth.

Materials for Each Group of Learners

Empty soup can, cat food can, Pringles® potato chip can, plastic soft drink bottle, and/or pie tin
Hammer (can be shared with other groups)
Nail
Water
Plastic bags or zip-type sandwich bags
Ruler
Cardboard
Masking or duct tape

Procedure

Have learners work in groups of 2-4 to do the following:

1. Use a hammer and a nail to puncture each of the containers at ½″ from the bottom.
2. Cover the holes with tape.
3. Predict what will happen when liquid is poured into each container. Predictions may be written by each group or discussed together by all class members.

NOTE: Due to the laws of fluid dynamics, the fluid in the tallest container would spew the farthest because the depth is greatest (given that all cans are filled).

---

4. Pour water into each of the containers.
5. Observe similarities and differences in the behavior of the fluid in each container.
6. Discuss what happened and why. Think of everyday examples that involve this principle.

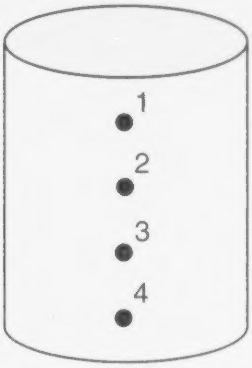
7. To illustrate the importance of patching the holes from the inside, ask learners to patch the hole in the Pringles® can or other container with a plastic bag or masking tape. Allow learners to experiment with using patching materials on both the inside and the outside of the container.

NOTE: Tape that is used on the outside of the container will not stick well. Also, the lowest hole would bulge a bit. When cardboard patches are affixed to the outside of the container, there is no leakage.

8. Learners might find that more than one of the choices is an effective alternative for plugging the hole. In this case, help learners weigh the alternatives in order to arrive at the BEST answer, paying special attention to cause-effect relationships. Learners should identify the potential effects of each of those solutions, and then judge which is the safest, easiest, and most cost-effective to use.

Problem

A stainless steel reservoir filled with cutting oil sits in a corner of the shop. A machine accidentally shoots out four slugs of metal, puncturing the reservoir in four different places, as indicated in the diagram attached. Assume each hole is identical in size. Your boss asks you to stop the leaks with as little spillage as possible. (Refer to the following diagram when answering the following questions.)



Identify the Problem

1. What have you been asked to do?
   A. Shut off the machine.
   B. Refill the reservoir with cutting oil.
   C. Empty the reservoir.
   D. Plug the holes in the reservoir.
   E. Call in an expert for help.

Define the Problem

2. What action should be taken to provide for the least amount of cleanup?
   A. Drain the oil from the drum.
   B. Shut off the machine.
   C. Fill the drum with oil-dry.
   D. Determine which hole pushes a stream of oil farthest from the drum.
   E. Turn the reservoir on its side so the holes point upward.

3. Examine the diagram. How do the mechanical properties of fluid pressure relate to the tank of liquid?
   A. Hole 4 would have the greatest pressure.
   B. Hole 3 would have the greatest pressure.
   C. Hole 2 would have the greatest pressure.
   D. Hole 1 would have the greatest pressure.
   E. All holes would have equal pressure.

Explore Alternatives

4. To lose as little cutting oil as possible, in what order would you repair the holes?
   A. Repair hole 2 first, then 3, 4, and 1.
   B. Repair hole 4 first, then 3, 2, and 1.
   C. Repair hole 1 first, then 2, 3, and 4.
   D. It doesn't matter which order you choose.
   E. The reservoir is unusable.

Act on a Plan

5. If you patch the bottom hole first, what would you expect to happen to the fluid passing through the remaining three holes?
   A. Pressure increases in Hole 3, but not in Holes 2 and 1.
   B. Pressure decreases in Hole 3, but not in Holes 2 and 1.
   C. Pressure remains the same in all three remaining holes.
   D. Pressure increases in all three remaining holes.
   E. Pressure decreases in all three remaining holes.

6. Which of the following solutions might best solve the leaking reservoir problem permanently?
   A. Patch the four holes from the inside of the reservoir.
   B. Use duct tape on the outside of the reservoir.
   C. Line the reservoir with a plastic can liner.
   D. Don't fill the reservoir higher than the level of the lowest hole.
   E. Patch the four holes from the outside of the reservoir.

Look at the Result

7. Which would be the most effective way to discover whether or not the patches you applied to the reservoir are an effective solution to the leakage problem before putting the reservoir back into use?
   A. Fill the reservoir with water and look for leaks.
   B. Fill the reservoir with oil and look for leaks.
   C. Fill the reservoir with air under pressure and attach a pressure gauge.
   D. Fill the reservoir with oil-dry and look for leaks.
   E. Place a flashlight in the reservoir and look for light on the exterior.

Fluid Dynamics Problem 3.2

Answers

1. D
2. D
3. A
4. B
5. C
6. A
7. C

Instructor's Notes:

Instructional Support Materials

Fluid dynamics

Fluid Dynamics Problem 3.3: Water Tanks

Scientific Principle

The relationship between fluid depth and pressure; as fluid depth increases, fluid pressure increases.

Background

This principle was chosen because of its many workplace applications, including the following:

- Medical and intravenous drips
- Material flows for industrial use
- Scuba diving
- Bottled water supplies
- Firefighting
- Pressure required for deep water wells

Key Process Skills

(Refer to p. 24 for a description of each process skill.)

●	Observing
●	Communicating
●	Comparing
○	Ordering
○	Making models
●	Measuring
●	Recording
●	Interpreting data
○	Experimenting
●	Predicting
○	Hypothesizing
●	Inferring
○	Categorizing or classifying
●	Recognizing relationships
○	Controlling variables

Ohio Science Proficiency Outcomes

(Refer to Appendix D, pp. 335-337, for a description of each outcome.)

6th Grade	9th Grade	12th Grade
1 ●	1 ●	1 ○
2 ○	2 ●	3 ●
3 ●	3 ●	4 ○
4 ○	4 ●	5 ○
5 ●	8 ○	8 ○
6 ○	9 ●	12 ○
7 ●	10 ○	
8 ●	11 ○	
9 ○	12 ○	
10 ●	17 ○	
	19 ○	

Vocabulary

Fluid
Pressure
Equidistant

The instructor may present some or all of the experiences that follow to instill an understanding of how to solve fluid dynamics problems.

Learning Activity 1

Materials for Each Individual or Group of 2-3 Learners

3 PVC pipes of different lengths (6", 12", 24"), each with 2" diameter
3 balloons
3 rubber bands
1 ruler
1 large cellulose sponge or sheet of foam rubber
Water

Procedure

1. As an introduction, help learners "visualize" pressure by showing the depression of a sponge when tubes of water are placed on it, as shown in the diagram below.

2. Stretch a section of balloon over one end of each of the three pieces of pipe and hold it in place with a rubber band.
3. Fill each tube with water and place on the sponge.
4. Observe the amount of depression caused by each of the tubes.
5. Measure the depression caused by each tube.
6. Determine the relationship of fluid depth to pressure exerted.
7. Write a statement summarizing that relationship.

Variation

Repeat the activity, using materials that are the same height but different diameters and/or shapes. This will allow learners to explore differences that occur when the same and different depths of water are used.

Learning Activity 2

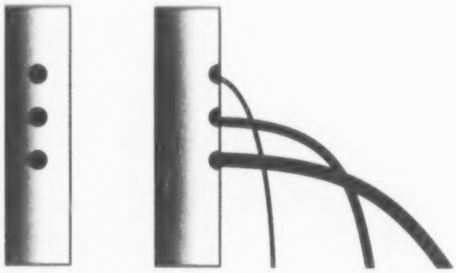
The next activity will show learners that pressure differs with water depth.

Materials

Prepare a solid tube with small, equal-size holes spaced equidistantly along the water column. Plug the holes with a toothpick.

Procedure

1. Ask learners to predict whether or not water pressure is affected by fluid depth. Have them describe what effects different amounts of pressure will have on water streaming from the tube.
2. With the tube filled with water, pull out the toothpicks in a variety of different sequences. Learners will observe that the deepest hole has the longest stream.
3. Have learners draw different fluid situations (e.g., dams, swimming pools, ponds) and describe why pressure will be greater or less in each structure, and a different levels of those structures.



Problem

You are the plumbing technician in charge of selecting a new water-storage tank for the company. The tanks available for purchase are all adequate to meet the company's water needs. You are responsible for selecting the tank that will deliver the most pressure at the outlet valve.

Identify the Problem

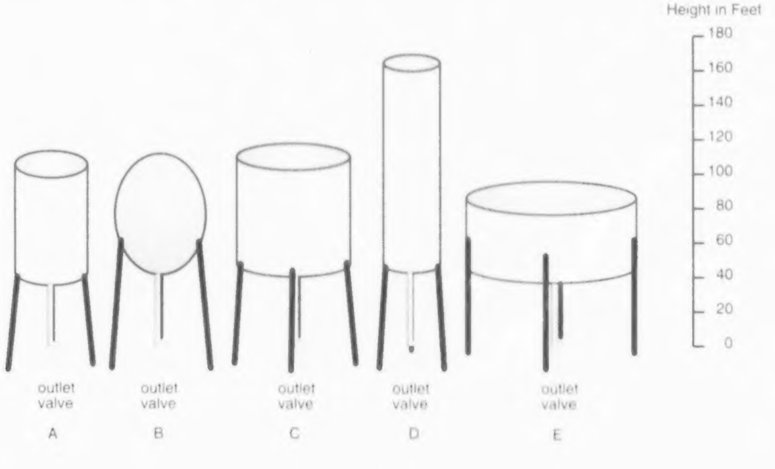
1. What is your assignment?
   - A. Choose the largest tank available.
   - B. Choose the tank with the highest pressure available at the outlet valve.
   - C. Pick which tank will fill up the fastest.
   - D. Pick the tank with the most capacity.
   - E. Choose the tank that will cost the least.

Define the Problem

2. Since the outlet valve is at the bottom of the tank, the pressure in the tank you select will be determined by ____________________.
   - A. The shape of the tank
   - B. The volume of the fluid stored
   - C. The size of the valve
   - D. The height of the fluid
   - E. The diameter of the tank

Explore Alternatives

3. Of the alternatives shown in the diagram below, which tank provides the greatest fluid height?
   - A. A
   - B. B
   - C. C
   - D. D
   - E. E


Height in Feet
180
160
140
120
100
80
60
40
20
0
outlet valve
A
outlet valve
B
outlet valve
C
outlet valve
D
outlet valve
E

Act on a Plan

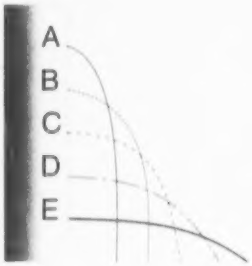
4. Examine the previous diagram. Which tank has the greatest fluid height—from the valve to the top of the water?

   A. A
   B. B
   C. C
   D. D
   E. E

Look at the Result

5. Given the situation in the diagram below, which stream has the greatest pressure?

   A. A
   B. B
   C. C
   D. D
   E. E



Answers

1. B
2. D
3. D
4. D
5. E

Instructor's Notes:

Instructional Support Materials

Fluid Dynamics Problem 3.4: Workstation Lubricator

Scientific Principle

The basic principles of fluid dynamics; flow through systems is affected by the power source, pressure, and resistance in the flow path.

Background

At Level 3, workers need to understand how to follow the flow of fluids and gases through systems in the workplace. In addition, Level 3 learners can begin to understand the flow of electricity through wires by analyzing the flow of fluids and gases.

Key Process Skills

(Refer to p. 24 for a description of each process skill.)

●	Observing
●	Communicating
●	Comparing
○	Ordering
○	Making models
●	Measuring
○	Recording
●	Interpreting data
●	Experimenting
●	Predicting
●	Hypothesizing
●	Inferring
●	Categorizing or classifying
●	Recognizing relationships
●	Controlling variables

Ohio Science Proficiency Outcomes

(Refer to Appendix D, pp. 335-337, for a description of each outcome.)

6th Grade	9th Grade	12th Grade
1 ○	1 ○	1 ○
2 ○	2 ●	3 ●
3 ●	3 ○	4 ○
4 ○	4 ○	5 ○
5 ○	8 ○	8 ○
6 ●	9 ●	12 ○
7 ●	10 ●	
8 ●	11 ○	
9 ○	12 ○	
10 ●	17 ○	
	19 ●	

Vocabulary

Fluid
Power source
Flow
Flow valve
Pressure
Resistance

Instructors can help learners understand how to solve flow-related problems by facilitating some or all of the learning activities described below.

Learning Activity 1

Conduct a discussion about the flow of fluids or air through systems. Ask learners to identify systems (machines and equipment) that involve fluid or air flow.

Learning Activity 2

Pick one or more of the systems discussed in the previous activity. Have learners trace the flow of fluid or air through the given system. In addition, have them identify where the system can be shut off and what components will be affected when the shutoff occurs. Ask them to identify factors that affect flow and pressure (e.g., the size of the hose affects pressure; the number of curves affects the flow).

Learning Activity 3

Have learners design a lawn-sprinkler system for a home. It should have 1 water source, at least 4 watering zones, and at least 4 hand-operated shut-off valves.

Learning Activity 4

Using the diagrams created in the previous learning activity, tell each learner where there is a hypothetical leak in their sprinkler system. Have learners work in pairs to determine which valve should be shut off to stop the leak.

Learning Activity 5

Use the Five Es of Instruction format, which is described on pp. 14-16, to have learners work individually or in pairs to build systems that use aquarium pumps, air pumps, brass valves, and plastic tubing. Have them experiment with increases and decreases in water flow. Encourage learners to make predictions and test them. After they have time to explore the principle of flow, facilitate a discussion in which learners can make generalizations about the flow of water through systems. Then ask learners to discuss how the flow of electricity through wires is similar to the flow of liquid or air through hoses.

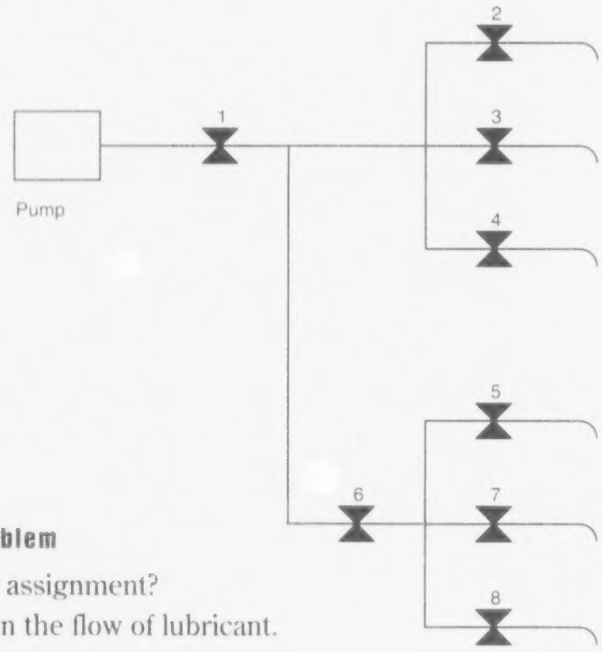
Learning Activity 6

In an activity similar to the previous one, have learners experiment with air flow by building systems that include a compressor, air hoses of varying lengths and diameters, and brass valves. Then ask learners to discuss how the flow of electricity through wires is similar to the flow of liquid or air through hoses.

Problem

You are the technician responsible for keeping 6 workstations operational. One pump provides lubricant to the 6 stations. There are 8 hand-operated valves that allow you to keep some workstations open while shutting down others.

Your supervisor tells you to stop the flow of lubricant to half of the stations as quickly as possible. Which valve(s) should you close to complete your assignment? Refer to the following diagram to answer the questions below.



Identify the Problem

1. What is your assignment?
   - A. Slow down the flow of lubricant.
   - B. Speed up the flow of lubricant.
   - C. Shut 4 valves.
   - D. Shut off the pump.
   - E. Shut off lubricant to 3 workstations.

Define the Problem

2. What is the BEST way to stop the flow of lubricant as required by your supervisor?
   - A. Shut off the pump.
   - B. Shut off 1 valve.
   - C. Shut off 2 valves.
   - D. Shut off 3 valves.
   - E. Shut off all valves.

Explore Alternatives

3. What will happen if you shut off Valve 1?
   A. All workstations will receive lubricant.
   B. No workstations will receive lubricant.
   C. One workstation will receive lubricant.
   D. Two workstations will receive lubricant.
   E. Three workstations will receive lubricant.

4. What will happen if you shut off Valve 2?
   A. All workstations will receive lubricant.
   B. No workstations will receive lubricant.
   C. Three workstations will receive lubricant.
   D. Four workstations will receive lubricant.
   E. Five workstations will receive lubricant.

5. What will happen if you shut off Valve 7?
   A. All work stations will receive lubricant.
   B. No work stations will receive lubricant.
   C. Three work station will receive lubricant.
   D. Four work stations will receive lubricant.
   E. Five work stations will receive lubricant.

Act on a Plan

6. Which valve(s) should you shut off to stop the flow of lubricant as required by your supervisor?
   A. Valve 1
   B. Valves 1 and 5
   C. Valves 3 and 4
   D. Valve 6
   E. Valves 1 and 6

Look at the Result

7. How will you know that you accomplished your assigned task?
   A. Confirm that the pump is shut off.
   B. Confirm that all valves are closed.
   C. Confirm that 3 work stations are not receiving lubricant.
   D. Confirm that 4 work stations are not receiving lubricant.
   E. Ask your supervisor.

Fluid Dynamics Problem 3.4

Answers

1. E
2. B
3. A
4. E
5. E
6. D
7. C

Instructor's Notes:

Instructional Support Materials

Fluid Dynamics Problem 3.5: Dust Collector

Scientific Principle

The basic principles of fluid dynamics; flow through systems is affected by the power source, pressure, and resistance in the flow path.

Background

At Level 3, workers need to understand how to follow the flow of fluids and gases through systems in the workplace. In addition, Level 3 learners can begin to understand the flow of electricity through wires by analyzing the flow of fluids and gases.

Key Process Skills

(Refer to p. 24 for a description of each process skill.)

●	Observing
●	Communicating
●	Comparing
◐	Ordering
◐	Making models
●	Measuring
◐	Recording
●	Interpreting data
●	Experimenting
●	Predicting
●	Hypothesizing
●	Inferring
●	Categorizing or classifying
●	Recognizing relationships
●	Controlling variables

Ohio Science Proficiency Outcomes

(Refer to Appendix D, pp. 335-337, for a description of each outcome.)

6th Grade	9th Grade	12th Grade
1 ◐	1 ◐	1 ◐
2 ◐	2 ●	3 ●
3 ●	3 ◐	4 ●
4 ◐	4 ◐	5 ◐
5 ◐	8 ◐	8 ◐
6 ●	9 ●	12 ◐
7 ●	10 ●	
8 ●	11 ◐	
9 ◐	12 ◐	
10 ●	17 ◐	
	19 ●	

Vocabulary

Dust collector
Duct
Filter
Air inlet
Exhaust blower
Blower motor
Dust inlet
Exhaust duct

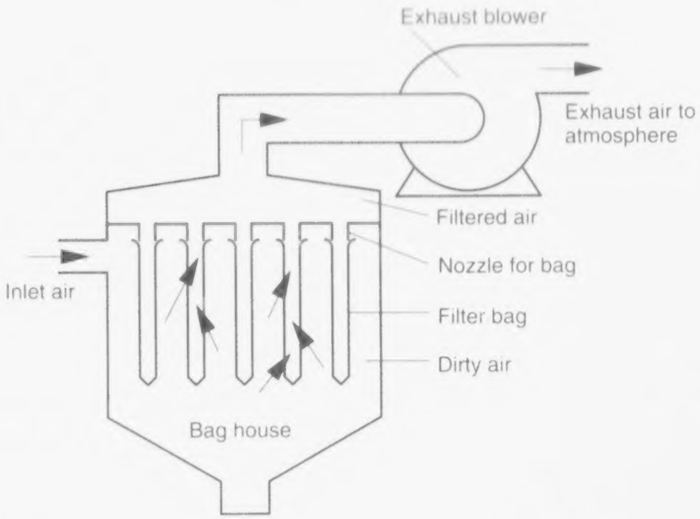
Learning Activities

This problem addresses principles similar to those of Problem 3.4. The same instructional strategies apply to both problems.

Problem

A dust-collection system removes airborne dusts from the work area. These dusts are carried in air ducts to a dust collector, which is called a bag house. Then the filtered air is exhausted to the atmosphere. You are responsible for keeping production going in your department. As you are walking through the production area, you notice a sudden change in the operation of the bag house. All dust inlets are sucking noticeably more air, and the exhaust duct from the bag house is blowing a visible dust stream into the atmosphere. Refer to the diagram below to answer the following questions.

Dust Collector System



Identify the Problem

1. What is the problem with the system?
   - A. The air inlet is blocked.
   - B. The exhaust blower quit working.
   - C. The air duct is clogged.
   - D. Exhaust air flow has increased; dust is blowing into the atmosphere.

Define the Problem

2. What action(s) should you take FIRST to investigate the problem?
   - A. Check the blower motor's rpm.
   - B. Measure the dust in the exhaust air.
   - C. Open the bag house; check for torn or missing bags.
   - D. Close the dust pickup vents; put on a respirator.

Explore Alternatives

3. How would you go about verifying the problem?
   - A. Check the current on the blower motor.
   - B. Check the bag house for missing bags; then check for torn bags.
   - C. Measure air flow at the dust-inlet vents.
   - D. Strap a furnace filter over the exhaust duct.

Act on a Plan

4. How would you restore the bag house's effectiveness?
   - A. Strap a furnace filter over the exhaust duct.
   - B. Increase the exhaust blower rpm.
   - C. Adjust the dust-inlet vents.
   - D. Replace missing or torn bags.

Look at the Result

5. How would you evaluate your remedy?
   - A. Check the current blower motor.
   - B. Start the dust collection system; look for dust in the exhaust.
   - C. Measure the rpm of the exhaust blower with a tachometer.
   - D. Check air ducts for dust accumulation.

Fluid Dynamics Problem 3.5

Answers

1. D
2. C
3. B
4. D
5. A

Instructor's Notes:

Instructional Support Materials

Wall switch
Electricity
110 V Outlet

Electricity Problem 3.6: Hair Dryer

Scientific Principle

Basic principles of electricity, including power sources and the flow of electricity through circuits.

Background

Once learners understand the basic principles of electricity, solving electrical problems becomes a matter of deductive reasoning. Problems 3.6 and 3.7 provide opportunities for learners to practice the process skills required to solve electrical problems.

Key Process Skills

(Refer to p. 24 for a description of each process skill.)

●	Observing
◐	Communicating
●	Comparing
◐	Ordering
◐	Making models
◐	Measuring
◐	Recording
◐	Interpreting data
●	Experimenting
●	Predicting
●	Hypothesizing
●	Inferring
●	Categorizing or classifying
●	Recognizing relationships
●	Controlling variables

Ohio Science Proficiency Outcomes

(Refer to Appendix D, pp. 335-337, for a description of each outcome.)

6th Grade	9th Grade	12th Grade
1 ◐	1 ◐	1 ●
2 ●	2 ●	3 ◐
3 ●	3 ●	4 ◐
4 ◐	4 ◐	5 ◐
5 ●	8 ◐	8 ◐
6 ◐	9 ◐	12 ◐
7 ◐	10 ●	
8 ◐	11 ◐	
9 ◐	12 ◐	
10 ●	17 ◐	
	19 ●	

Vocabulary

Electrical power source
Flow
Circuit
Current

The following activities will help learners gain and practice the skills involved in analyzing basic electrical problems. Instructors may wish to refer to the list of system-analysis questions that appears on pp. 19-22.

Learning Activity 1

The best way to help learners understand the basic principles of electricity is to give them opportunities to experiment with electrical equipment: batteries, coated copper wires, flashlight bulbs. Sometimes Christmas lights that have been cut into one-bulb sections can be used in place of wires and bulbs. To foster inquiry-based learning, introduce learners to the learning activities described in the Five Es of Instruction example provided on pp. 14-16.

NOTE: The inquiry-based learning activities are meant to help learners understand basic electrical principles. Instructors may need to plan more challenging learning activities for male learners and those with knowledge of basic electrical principles. Many activities are provided in the instructional support materials designated for Level 4 and 5 electricity problems.

Learning Activity 2

Conduct activities similar to those suggested in Problem 3.4, which involves the flow of fluids and air. Have learners analyze an electrical system.

Learning Activity 3

Have learners work in pairs or small groups to follow the flow of power through electrical systems (e.g., toaster, stereo system, car, television and VCR that are connected).

Learning Activity 4

Have learners work individually or in small groups to draw a machine that uses electricity as its primary power source. Have them identify how the power flows through the system and how different parts are affected by the power. Ask them to predict what would happen if the power to specific parts was cut off.

Electricity Problem 3.6

Problem

Problem

After showering in her bathroom with all of the lights on, Pam plugged her hair dryer into the outlet next to the sink in the bathroom. The hair dryer would not turn on. She then plugged the hair dryer into the outlet next to the sink in her second bathroom. It worked. She plugged it into her bedroom outlet and it worked. She called an electrician who had just done some work in her basement. What advice should the electrician give Pam to fix her problem?

Identify the Problem

1. What piece of equipment is presenting problems for Pam?
   - A. The lighting circuit in the second bathroom
   - B. The outlet in the first bathroom
   - C. The outlets in both bathrooms
   - D. All of the outlets in her house
   - E. The lighting circuit in the first bathroom

Define the Problem

2. Which statement BEST describes Pam's problem?
   - A. The hair dryer is broken.
   - B. Pam cannot use the lights and the outlet in the bathroom at the same time.
   - C. All of the outlets in the house are not working.
   - D. The outlets in the two bathrooms are not working.
   - E. The outlet in the first bathroom is not working.

Explore Alternatives

3. What is the MOST LIKELY cause of Pam's problem?
   - A. Her hair dryer is damaged.
   - B. There is not enough power going to the lights in the bathroom.
   - C. There is too much power going to the lights in the bathroom.
   - D. The electrician wired the basement circuit wrong.
   - E. The outlet in her bathroom is not working properly.

Act on a Plan

4. The electrician should tell Pam to
   A. Buy a new hair dryer.
   B. Turn off all of the lights in the bathroom before drying her hair.
   C. Hire an electrician to rewire her house.
   D. Check the electrical circuit in her bathroom.
   E. Not use the outlets in her bathroom because they are dangerous.

Look at the Result

5. How will Pam know that the problem has been resolved?
   A. Anything that she plugs into her bathroom outlet will work.
   B. When plugged into the outlet in her bathroom, Pam's hair dryer will work.
   C. Pam's hair dryer will work in her bathroom but not in her home's second bathroom.
   D. None of the above are true.
   E. A and B are true.

Electricity Problem 3.6

Answers

Answers

1. B
2. E
3. E
4. D
5. E

Instructor's Notes:

Instructional Support Materials

Electricity

Electricity Problem 3.7: Wonderware Computer

Scientific Principle

Basic principles of electricity, including power sources and the flow of electricity through circuits.

Background

Once learners understand the basic principles of electricity, solving electrical problems becomes a matter of deductive reasoning. This problem provides an opportunities for learners to practice the process skills required to solve electrical problems.

Key Process Skills

(Refer to p. 24 for a description of each process skill.)

●	Observing
○	Communicating
●	Comparing
○	Ordering
○	Making models
○	Measuring
○	Recording
○	Interpreting data
●	Experimenting
●	Predicting
●	Hypothesizing
●	Inferring
●	Categorizing or classifying
●	Recognizing relationships
●	Controlling variables

Ohio Science Proficiency Outcomes

(Refer to Appendix D, pp. 335-337, for a description of each outcome.)

6th Grade	9th Grade	12th Grade
1 ○	1 ○	1 ●
2 ○	2 ●	3 ○
3 ●	3 ●	4 ○
4 ○	4 ○	5 ○
5 ●	8 ○	8 ○
6 ○	9 ○	12 ○
7 ○	10 ●	
8 ○	11 ○	
9 ○	12 ○	
10 ●	17 ○	
	19 ○	

Vocabulary

Power source
Flow
Current
Breaker

Learning Activities

This problem addresses principles similar to those of Problem 3.6. The same instructional strategies apply to both problems.

Problem

An operator is running Line 6 of a plastics production plant. She observes that the Wonderware computers that control the line suddenly lose power. What should the operator do to correct the problem?

Identify the Problem

1. What does the operator need to do?
   - A. Call her supervisor.
   - B. Get the line running.
   - C. Reprogram the computer.
   - D. Get the electricity back on.

Define the Problem

2. Which statement BEST describes the problem?
   - A. The computer system shut down.
   - B. There is no communication with the manufacturing process.
   - C. The extruder will not start.
   - D. The power is off.

Explore Alternatives

3. What is the MOST LIKELY cause of the problem?
   - A. A tripped breaker
   - B. A faulty computer
   - C. A power outage to the plant
   - D. An unplugged computer

Act on a Plan

4. What should the operator do FIRST?
   - A. Call her supervisor for advice.
   - B. Call maintenance to check out the problem.
   - C. Go to the Power Panel book; locate the breaker that feeds the computers.
   - D. Reset all the breakers.

Look at the Result

5. Once the problem has been corrected, how can it be avoided in the future?
   - A. Know what caused the breaker to trip.
   - B. Have maintenance wire the circuit correctly.
   - C. Replace the computer.
   - D. Install a surge protector.

Answers

1. A
2. A
3. A
4. C
5. A

Instructor's Notes:

Instructional Support Materials

Mechanics

Mechanics 3.8: Overheating Car

Scientific Principles

Basic understanding of simple machines (e.g., pulleys) and how they lighten the workload by increasing force.

Background

Simple machines are useful tools in everyday life. Learners need to have a basic understanding of simple machines—for example, the pulley. A pulley is a machine made up of one or more wheels and a rope, belt, or chain. Pulleys are important parts of small engines and automobiles. A pulley is a type of lever that is a wheel with a groove in its rim. It is used to change the direction of a force. A pulley or system of pulleys can also multiply forces.

Key Process Skills

(Refer to p. 24 for a description of each process skill.)

●	Observing
●	Communicating
●	Comparing
◐	Ordering
●	Making models
◐	Measuring
◐	Recording
●	Interpreting data
●	Experimenting
◐	Predicting
◐	Hypothesizing
●	Inferring
●	Categorizing or classifying
●	Recognizing relationships
◐	Controlling variables

Ohio Science Proficiency Outcomes

(Refer to Appendix D, pp. 335-337, for a description of each outcome.)

6th Grade	9th Grade	12th Grade
1 ●	1 ●	1 ●
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3 ●	3 ●	4 ●
4 ◐	4 ◐	5 ◐
5 ●	8 ●	8 ●
6 ●	9 ●	12 ◐
7 ●	10 ◐	
8 ◐	11 ◐	
9 ◐	12 ◐	
10 ◐	17 ●	
	19 ●	

Vocabulary

Fixed pulley
Movable pulley
Block and tackle pulley system
Coolant system
Radiator
Belt

Each of the following activities will help learners understand mechanical systems. Instructors are advised to allow considerable time for learners to participate in these activities.

Learning Activity 1

Discuss and, if possible, demonstrate some everyday things that incorporate the use of pulleys, including the following:

Windows: fixed pulley system (A pulley stays in place as a cord moves over the wheel.)
Clothesline: fixed pulley system
Flagpole pulley system: fixed pulley system
Window-washer platform: block and tackle pulley system
Dentist drill: block and tackle pulley system
Shoe laces: moveable pulley system (The eyelets act as pulleys that move the sides of the show toward the center when the laces are pulled.)

Compare and contrast how work is done with each everyday example. In addition, help learners create a chart listing places where pulleys may be found and how they help do work. (Refer to the Basic Scientific Principles in Appendix C, pp. 327-333, for additional information about pulleys.)

Learning Activity 2

Have learners design, construct, and operate a simple pulley device. For example, learners could design a clothesline-like system that sends papers to a specified location.

Learning Activity 3

Use bobbins, yo-yos, oreo-type cookies, spools, or caps from soft drink bottles, along with string or rope, to have learners see for themselves how pulleys work (through demonstrations and hands-on experiences). Many activities are suggested in the books listed in the Reference section, Appendix B, pp. 307-325.

Learning Activity 4

Have learners use commercial equipment (e.g., LEGO®, Erector®, K-nex®, or Capsella®) to build simple machines using pulleys.

Learning Activity 5

Expand the use of simple pulleys to more complex machines, including the following:

- Exercise equipment (e.g., Nautilus®)
- Automatic transmission
- Dot-matrix printer
- Farming equipment used to do lifting
- Engine hoist
- Lawn mower deck
- VCR

Learning Activity 6

Have learners take apart several types of pulley systems to observe how work is done.

Learning Activity 7

Look under the hood of a car and point out the pulley and fan-belt system.

Learning Activity 8

Use flowcharts and diagrams to help learners develop skill in reading them.

Learning Activity 9

Use instruction sheets that accompany everyday toys, equipment, and machines to give learners practice in reading diagrams (e.g., assembly instructions from a new vacuum cleaner, bicycle, or prefabricated computer table).

Learning Activity 10

Have learners participate in one or more of the problem-solving activities described on pp. 26-32.

Learning Activity 11

Have learners analyze a mechanical system by answering the questions on pp. 19-21.

Mechanics Problem 3.8

Problem

You work in a garage. A car pulls into the gas station with steam pouring out from under the hood. The driver tells you that the temperature light is on and asks for help. After instructing the customer to turn off the vehicle, you make a visual inspection for loose or broken parts. It is your responsibility to determine what the problem might be.

Identify the Problem

1. What is your assignment?
   - A. Locate the reason the car is overheating.
   - B. Pump gas into the car.
   - C. Take the car for a test drive.
   - D. Pour cold water over the radiator.
   - E. Get a fire extinguisher.

Define the Problem

2. How will you locate the problem?
   - A. Look at the electrical system in the car.
   - B. Inspect the fuses inside the car.
   - C. Check for gas leaks.
   - D. Check the exhaust system.
   - E. Open the hood and visually inspect the engine area.

Explore Alternatives

3. What will you do?
   - A. Inspect for a broken belt between the pulley and the water pump.
   - B. Make sure the air filter is in place.
   - C. Smell for burning rubber.
   - D. Taste the water dripping off the hose to see if it contains antifreeze.
   - E. Make sure the battery cables are connected.

Act on a Plan

4. Which step will you take FIRST to correct the situation?
   A. Replace the air filter.
   B. Replace the thermostat.
   C. Adjust the idle to slow the motor down.
   D. Tighten the battery cables.
   E. Replace the broken belt between the pulley and the water pump.

Look at the Result

5. After replacing the belt and replenishing the fluid, you start the motor and let the car run. The car does not overheat again. What should you do now?
   A. Call the customer over and explain what you've done.
   B. Call the EPA to report and antifreeze spill.
   C. Replace the thermostat.
   D. Tell the customer not to drive the car for at least two hours.
   E. Change the temperature gauge.

Mechanics Problem 3.8

Answers

1. A
2. E
3. A
4. E
5. A

Instructor's Notes:

Mechanics Problem 3.9: Clock Gears

Scientific Principle

The driven gear moves in the opposite direction from the drive gear. An idler gear, when placed between a drive gear and a driven gear, allows the drive and driven gears to move in the same direction.

Background

Understanding how gears work in tandem with each other is critical to understanding systems that include gears. Learners need to understand the logic behind gear configuration and the cause-effect relationship between gears. They need to understand that the drive gear and the driven gear move in opposite directions.

Key Process Skills

(Refer to p. 24 for a description of each process skill.)

●	Observing
●	Communicating
●	Comparing
○	Ordering
●	Making models
○	Measuring
○	Recording
○	Interpreting data
●	Experimenting
●	Predicting
○	Hypothesizing
○	Inferring
●	Categorizing or classifying
●	Recognizing relationships
●	Controlling variables

Ohio Science Proficiency Outcomes

(Refer to Appendix D, pp. 335-337, for a description of each outcome.)

6th Grade	9th Grade	12th Grade
1 ○	1 ●	1 ●
2 ●	2 ○	3 ●
3 ●	3 ●	4 ●
4 ○	4 ○	5 ○
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6 ●	9 ●	12 ○
7 ●	10 ○	
8 ○	11 ○	
9 ○	12 ○	
10 ○	17 ●	
	19 ●	

Vocabulary

Driven gear
Drive gear
Idler gear

Instructors can help learners understand gear relationships and mechanical problem solving by facilitating the learning activities below.

Materials for Each Group of 2-4 Learners

At least 3 gears (more if using gears of various sizes)
Cardboard cutouts of clock hands that can be attached to the proper gear(s)
A large clock (so that learners can visualize the process)

Learning Activity 1

Have learners experiment by combining gears of various sizes to gain an understanding of the relationship between them. Learners should come to understand the patterns and interconnections of gears; that the driven gear moves in the opposite direction from the drive gear. (In Problem 3.9, the drive gear moves clockwise, so there is no way for the clock to keep accurate time without repair.)

Learning Activity 2

As a continuation of the previous activity, have learners add an idler gear between the drive and driven gears. They will discover that idler gear rotates in the opposite direction from the drive gear, and therefore turn the drive gear in the same "clockwise" direction as the driven gear. In addition, learners will come to understand that the drive gear and the driven gear may not touch each other if they are to turn in the same direction.

This may be a good time to teach learners about gear ratios. However, for Level 3 problems, gear ratio is a higher-level concept.

Learning Activity 3

Learners sometimes need help evaluating choices. Sometimes choices that are most obvious to the instructor are not as obvious to learners. The instructor can ask learners to make predictions. For example, learners can be directed to make predictions when they discuss the merits of each of the choices in Targets for Learning problems—before choosing any of them. Learners might be surprised to find that some of the other choices would work. (This is important because, in business and industry, workers need to have backup plans just in case the most obvious plan doesn't produce the needed results.)

NOTE: When discussing Problem 3.9, help learners resist the temptation to use extraneous information. Four of the options deal with the rate of speed. Although four of five choices may deal with a particular issue, that issue might still be extraneous.

Problem

You have inherited a beautiful antique clock from your grandmother. Everything seems to be in working order. You set the clock for 4:00, which is the current time. A half hour later, the clock reads 3:30. Refer to Diagram 3.91, to answer the following questions.

Identify the Problem

1. Is the clock keeping accurate time?
   A. Yes.
   B. No.
   C. Yes, but it is keeping time backwards.
   D. No, it is running slow.
   E. No, it is running fast.

Define the Problem

2. What might you determine to be the problem with the clock?
   A. The clock's hands are moving too fast.
   B. The clock's hands are moving too slowly.
   C. The clock's hands are moving in reverse, but at the correct rate.
   D. The clock's hands are moving in reverse and too slowly.
   E. The clock's hands are moving in reverse and too quickly.

3. How does the relationship between the drive gear and the driven gear on the inside of the clock affect the clock's hands?
   A. As the drive gear turns clockwise, the driven gear turns counterclockwise.
   B. As the drive gear turns clockwise, the driven gear turns clockwise.
   C. As the drive gear turns clockwise, the driven gear stays stationary.
   D. The drive gear does not turn.
   E. There is no relationship between the drive gear and the driven gear.

Explore Alternatives

4. You must alter the clock so that it keeps correct time. Which method would be the BEST choice for clock alteration?
   - A. Create a chart of times so that you may identify the correct time based on what time the clock says.
   - B. Change the counterweight pulley.
   - C. Reverse the spring.
   - D. Reverse the numbers on the clock.
   - E. Add an idler gear to the gear mechanism.

Act on a Plan

5. In the attached diagram, what is the BEST gear arrangement for the clock?
   - A. A
   - B. B
   - C. C
   - D. D
   - E. E

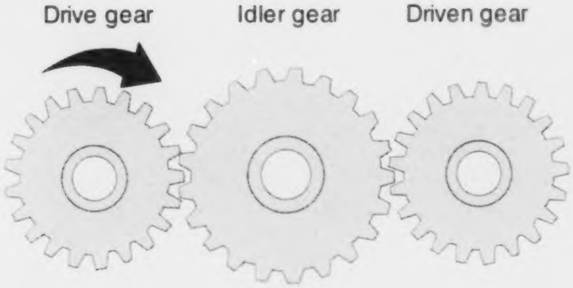
6. To which gear must the clock hands be attached?
   - A. Drive gear
   - B. Idler gear
   - C. Driven gear
   - D. Both the drive gear and the idler gear
   - E. None of the gears

Look at the Result

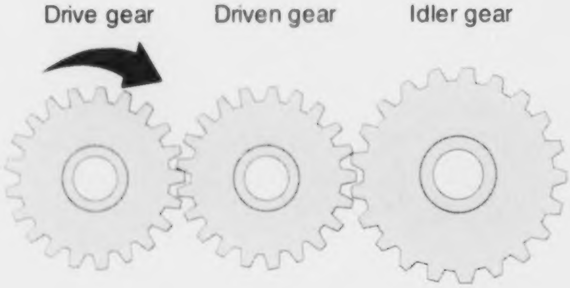
7. Which would be the most effective way to discover whether the changes you made to the gears in the clock are effective?
   - A. Telephone the local time and temperature service to see if the clock is correct.
   - B. Set the time for midnight and see if the hands move clockwise.
   - C. Watch the clock for 15 minutes and see if 15 minutes have truly passed.
   - D. Set the clock for the current time, and return in ten minutes to learn if the clock shows the accurate time.
   - E. Take the clock to a repair shop to have it evaluated.

Diagram 3.81

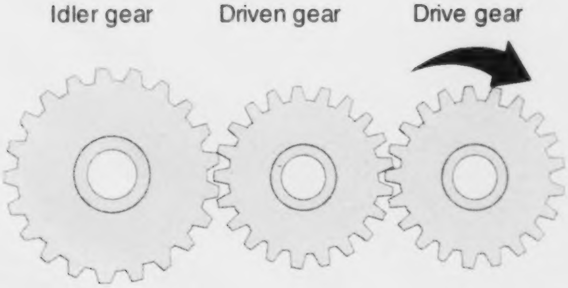
A.


Drive gear
Idler gear
Driven gear

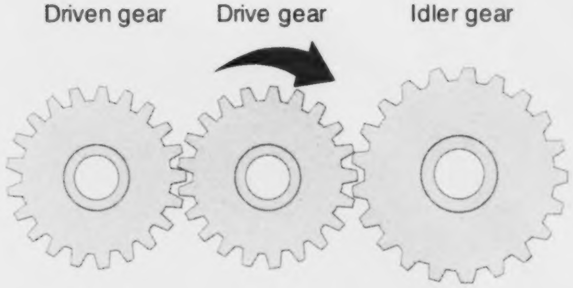
B.


Drive gear
Driven gear
Idler gear

C.


Idler gear
Driven gear
Drive gear

D.


Driven gear
Drive gear
Idler gear

E. None of the gear configurations will work.

Answers

1. C
2. C
3. A
4. E
5. A
6. C
7. D

Instructor's Notes:

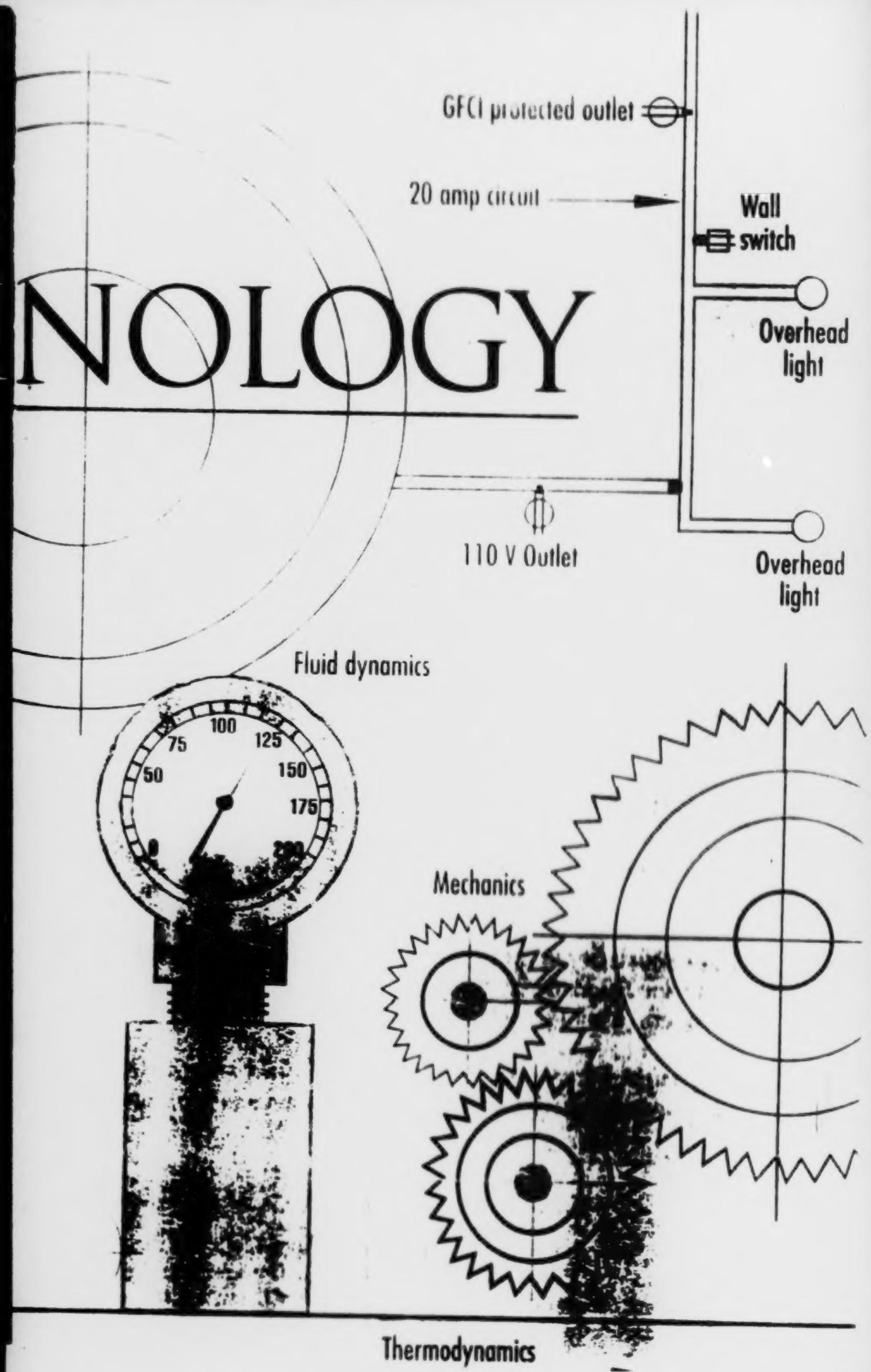
APPLIED TECHNOLOGY

TARGETS FOR LEARNING

LEVEL 4 LEARNING ACTIVITIES AND PROBLEMS

The learning activities and problems in this section are designed to help learners reach applied technology Level 4.

> *"As with any classroom demonstration, I would recommend that the teacher always try things first to make sure the results will be as expected before trying them in front of learners."*
>
> Pilot Instructor


GFCI protected outlet
20 amp circuit
Wall switch
Overhead light
110 V Outlet
Overhead light
Fluid dynamics
75
100
125
50
150
175
0
200
Mechanics
Thermodynamics

BEST COPY AVAILABLE

Improving to Level 4

As defined and measured by Work Keys, Level 4 learners can

- Apply elementary principles underlying the operation of physical systems to solve a problem (e.g, identifying the effect of resistance on flow, such as valves in water pipes, volume controls in radios, and dimmer switches in light circuits).
- Understand physical principles that are more abstract, less intuitive, and less observable than those at Level 3 (e.g., the flow of electricity is more abstract than the flow of water).
- Understand the operation of moderately complex tools, machines, or systems, such as home appliances, pulley-driven equipment, or piping systems that carry more than one fluid. Reading for information and locating information skills may be needed.
- Recognize and identify information relevant to solving the problem while disregarding extraneous information.
- Determine, as efficiently as possible, what to check first when inspecting a malfunctioning system or machine containing up to ten components that are potential sources of the problem.
- Solve problems that require a two-step process or that involve the manipulation of two variables to arrive at a solution.

The learning activities in this section are designed to help learners reach applied technology Level 4. In addition to presenting these activities, instructors may wish to use some of the books, software, and materials described in the Resource list, pp. 307-325, to—

- Gain a clearer understanding of the basic scientific principles involved in applied technology problems
- Select activities to supplement those in Targets for Learning
- Recommend resources to learners wishing to gain deeper insights about the basic scientific principles involved in applied technology problems

Improving to Level 4 Index

Problem Number	Category	Problem Topic	Page Number
4.1	Thermodynamics	Picnic Spatulas and Coolers	121
4.2	Thermodynamics	Machine Shop Bearings and Shaft	133
4.3	Fluid Dynamics	Garden Water Hose	141
4.4	Fluid Dynamics	Car Brakes	149
4.5	Electricity	Three-Way Light Switch	155
4.6	Electricity	New Home Amps	161
4.7	Electricity	Pan Conveyor Motor	171
4.8	Mechanics	Lawn Mower Valves	177

Thermodynamics Problem 4.1: Picnic Spatulas and Coolers

Scientific Principle

Heat conduction varies with the type of material through which heat flows. Basic principles of heat conduction include the following: darker-colored surfaces absorb more heat than light-colored surfaces and metal absorbs and conducts more heat than wood or plastic.

Background

Conduction is the transfer of heat throughout a material. This is done by the rapid vibration of the molecules nearest to the heat source. The vibration causes other molecules nearby to pick up some of this energy and vibrate also. This takes place throughout the material. Conduction is chiefly associated with solids because the closely packed molecular structure of a solid is best suited to it. Metals are good conductors of heat. In addition, dark colors absorb heat, and light colors reflect heat.

Key Process Skills

(Refer to p. 24 for a description of each process skill.)

●	Observing
●	Communicating
●	Comparing
◐	Ordering
◐	Making models
◐	Measuring
◐	Recording
●	Interpreting data
◐	Experimenting
●	Predicting
◐	Hypothesizing
●	Inferring
◐	Categorizing or classifying
●	Recognizing relationships
◐	Controlling variables

Ohio Science Proficiency Outcomes

(Refer to Appendix D, pp. 335-337, for a description of each outcome.)

6th Grade	9th Grade	12th Grade
1 ●	1 ◐	1 ●
2 ●	2 ●	3 ◐
3 ●	3 ●	4 ●
4 ●	4 ◐	5 ◐
5 ●	8 ◐	8 ◐
6 ◐	9 ◐	12 ◐
7 ◐	10 ◐	
8 ●	11 ●	
9 ●	12 ●	
10 ●	17 ●	
	19 ●	

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Vocabulary (see definitions on the attached matching exercise)

Conduction
Conductor
Absorption
Reflection
Molecules
Thermal
Transfer
Temperature
Quenching

To help learners master the principles involved in this problem, the instructor is encouraged to review conduction principles with learners and to provide a opportunities for them to learn for themselves how to discover the correct answers. As implied in this problem, if you bring the metal utensils and leave them in the sun, they will be too hot to handle. The plastic may melt in the sun. The wood is not a conductor of heat, so that appears to be the best choice to bring to the picnic, but it will burn in direct flame. If you bring the white cooler to the picnic, the ice will stay longer than in the black cooler because the black cooler absorbs heat while the white cooler reflects heat.

The learning activities described below may also be conducted:

Learning Activity1

Given a cup of hot chocolate with a spoon in it, learners experience that the spoon handle becomes hot to the touch because the heat is transferred (by conduction) through the metal. (Refer to Worksheet 4.11.)

Learning Activity 2

Demonstrate how metal is a good conductor of heat and wood is not (e.g., examine metal and wooden benches to see which are hot and which are cool).

Learning Activity 3

Darker-colored surfaces absorb more heat than light-colored surfaces due to differences in reflection and absorption of heat. This principle is demonstrated in the activity described in Worksheet 4.12.

Learning Activity 4

Have learners experience examples of quenching by touching a hot iron with a **wet** finger.

Discuss how people are able to walk over hot coals. (Don't try this at home!) The feet need to be moist (natural perspiration). Moisture absorbs some of the heat and provides an insulating layer between the soles of the feet and the coals. The wood coals must have a low-enough thermal conductivity so that if the feet were in contact very briefly, not much heat could pass through.

Learning Activity 5

Have learners experiment with heat transfer by participating in the activity that is described in Worksheet 4.13.

Learning Activity 6

Have learners demonstrate their understanding of the vocabulary related to thermodynamics by doing the matching activity provided on Worksheet 4.14.

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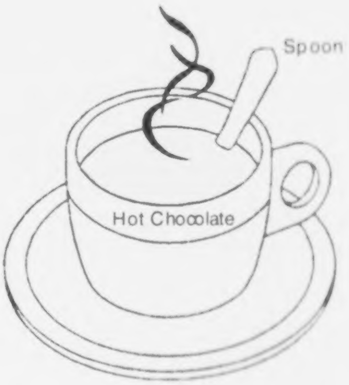
Conduction of Heat



Look at the diagram above. Answer the following questions with a team member or classmate.

- When the spoon is put into the hot chocolate, what happens to the temperature of the spoon? Why?

- Is the temperature at the bottom of the spoon the same as the temperature of the handle? Explain.

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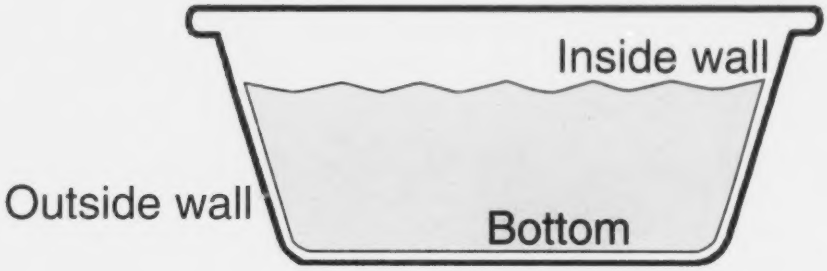
Reflection and Absorption of Heat

You want to leave a water dish out for your pet on a cold, sunny day. Study the diagram of the water dish. Discuss with a classmate what materials could be used on the bottom of the water dish. In addition, discuss what materials could be used on the inside and outside walls to keep the water warm.

Some materials to consider are

White stones or pebbles
Black stones or pebbles
Dark blue, green, or black paint
White paint
Aluminum foil
Mirrors
Black plastic
Clear plastic
White sand
Dark sand
Brown cardboard



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Thermodynamics Problem 4.1 — Worksheet 4.13

Heat Transfer

Materials for Each Group of 2-4 Learners

1 pie pan or other container that will hold water
1 full soft drink can (at room temperature)
1 clay flower pot (large enough to fit over the soft drink can)
Cool water

To gain an understanding of the principle of heat transfer, do the following:

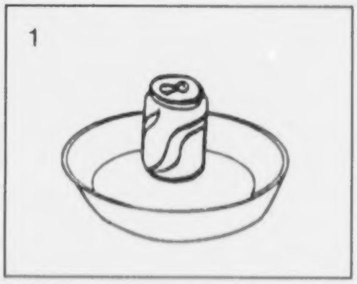
1. Put the soft drink can in the center of the pan.
2. Place the clay pot over the top of the can so that the can is completely covered. Pour cool water on top of the flower pot so that it is soaked and about an inch of water is in the pan).
3. Place this in direct sunlight.
4. Make a prediction about what you think will happen. In the space below, write an explanation for your prediction. Provide everyday examples of how you encounter this scientific principle.

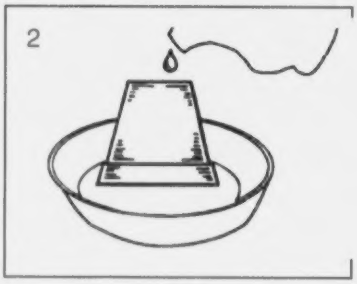
Prediction: ______________________________

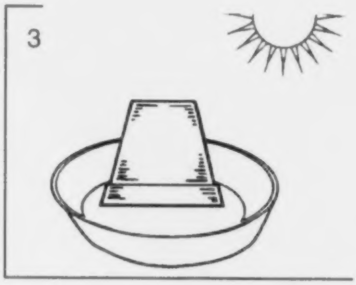
____

Explanation: ______________________________

____







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Thermodynamics Problem 4.1 Worksheet 4.14

Match each term in the left column with its definition in the right column.

absorption	a utensil for flipping food over to the other side
conduction	exchanging one substance for another
conductor	capable of transmitting heat
molecules	a tool for preparing and eating food
reflection	related to heat
spatula	a degree of hotness or coldness that is measured on a scale
temperature	turning back
thermal	the smallest particle of a substance that retains all the properties of the substance
transfer	interception of radiant energy
utensil	movement of heat through a solid object

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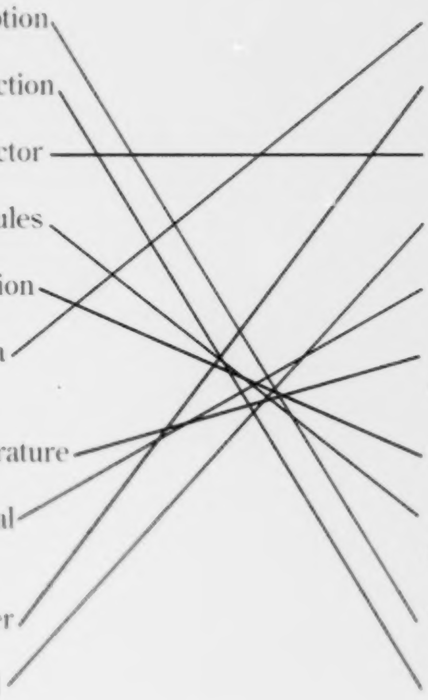
Explanation

Although the handle of the spoon does not touch the hot liquid at all, the handle becomes hot. The liquid heats the bottom of the spoon. The heat moves up the spoon to the handle. This movement of heat through a solid object is called **conduction**.

Explanation for Learning Activity 4.13

As the water evaporates, its vapor will carry heat away from the clay pot. This cools the air in the clay pot, which cools the can of soda. In about an hour, the soda should be cool enough to drink.

Answers for Worksheet 4.14



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thermal	the smallest particle of a substance that retains all the properties of the substance
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utensil	movement of heat through a solid object

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Problem

You are going to an outdoor picnic on a hot, sunny day. You are asked to bring a spatula for the grill and an ice chest. You have several spatulas and ice chests at home. You must choose which would be the best to bring to the picnic, from the following choices:

Spatulas:	all metal, all wood, metal with a wooden handle, black plastic
Ice chests:	white, black

Identify the Problem

1. What is your assignment for the picnic?
   A. Determine how much meat you will need to buy for 8 people.
   B. Check the weather forecast for the day of the picnic.
   C. Select the most appropriate spatula and ice chest to take to the picnic.
   D. Count the number of people who will attend the picnic.
   E. Buy block ice or chipped ice.

Define the Problem

2. What do you need to consider when selecting items for a picnic on a sunny day?
   A. Outside temperature and type of items needed.
   B. Outside temperature and how many people will attend the picnic.
   C. How many people will be at the picnic.
   D. How many pounds of meat to buy.
   E. The name of the park where the picnic will take place.

Explore Alternatives

It is a hot, sunny day and the picnic is outdoors. Answer the following questions to determine whether you should take the metal, wood, metal with a wooden handle, or plastic utensils and whether you should take a black or a white cooler.

3. If you select the all-wooden spatula, what will most likely happen when you grill?
   A. The spatula might catch fire.
   B. The spatula will burn your hand.
   C. The spatula will lose its form.
   D. Food will stick to the spatula.
   E. The spatula will lose its strength and break.

4. If you select the all-metal spatula, what will most likely happen when you grill?
   A. The spatula will transfer heat to your hand and burn it.
   B. The spatula will absorb juices from the meat.
   C. The spatula will stick to the meat.
   D. The spatula will add a metal taste to the meat.
   E. The spatula will burn and lose its shape.

5. If you select the plastic spatula, what will most likely happen when you grill?
   A. The spatula will burn your hand.
   B. The spatula will not lose its shape.
   C. The spatula will become brittle and break.
   D. The spatula will be OK if you quench it in water.
   E. The spatula will melt and lose its shape.

6. If you select the metal spatula with a wooden handle, what will most likely happen when you grill?
   A. The spatula will remain sturdy and will not conduct heat to your hand.
   B. The handle will separate from the metal.
   C. The spatula will give a metal taste to the meat.
   D. Food will stick to the spatula.
   E. The spatula will burn up.

7. If you select the black cooler for the picnic, what will most likely happen?
   A. Food will stay nice and cold in the black cooler.
   B. The black cooler will reflect heat, and the ice will not melt.
   C. Ants can get into either the black or white cooler.
   D. The inside temperature of the black cooler will remain stable.
   E. The black cooler will absorb heat and melt the ice within it more quickly than a light-colored cooler would.

8. If you select the white cooler for the picnic, what will most likely happen?
   A. The white cooler will stay clean.
   B. The white cooler will reflect heat, and the ice will stay longer than in a black cooler.
   C. Bees will be attracted to the white cooler.
   D. The white cooler will be easier to carry than the black cooler.
   E. The white cooler will absorb heat quickly and will cause the ice to melt.

Act on a Plan

9. Select the most appropriate supplies to bring to the picnic.
   - A. Bring the all-wooden utensil and a black cooler.
   - B. Bring the all-metal utensil and a white cooler.
   - C. Bring the plastic utensil and a black cooler.
   - D. Bring the metal spatula with the wooden handle and the white cooler.
   - E. Purchase a new cooler and a new spatula.

Look at the Result

10. You take the metal spatula with the wooden handle and the white cooler to the picnic. What are the effects or results of this choice?
    - A. You were able to flip all the hamburgers successfully and the cooler stayed cool.
    - B. You burned your hand, but the cooler stayed cool.
    - C. The spatula melted and so did the ice in the cooler.
    - D. The spatula caught fire and burned up, and the white cooler got dirty.
    - E. The spatula became brittle and broke, and the cooler leaked.

Answers

1. C
2. A
3. A
4. A
5. E
6. A
7. E
8. B
9. D
10. A

Instructor's Notes:

Instructional Support Materials

Thermodynamics Problem 4.2: Machine Shop Bearings and Shaft

Scientific Principle

Friction causes heat to be generated when systems operate. Friction can be reduced by providing lubrication to the system.

Background

In troubleshooting industrial problems, the technician must be very observant. Too much friction can lead to heat increases that affect machine performance and/or result in expensive machine repairs. Troubleshooting requires observing with as many senses as possible. A technician who works on the same machine for only a few hours will be able to detect whether sounds, vibrations, smells, and debris accumulation are different from normal.

Understanding the effect of lubrication on heat is essential to the maintenance of equipment in the workplace. The machine in this problem is similar to ones used to manufacture axles, bolts, and screws.

Key Process Skills

(Refer to p. 24 for a description of each process skill.)

●	Observing
●	Communicating
●	Comparing
○	Ordering
○	Making models
●	Measuring
●	Recording
●	Interpreting data
●	Experimenting
●	Predicting
○	Hypothesizing
●	Inferring
○	Categorizing or classifying
●	Recognizing relationships
●	Controlling variables

Ohio Science Proficiency Outcomes

(Refer to Appendix D, pp. 335-337, for a description of each outcome.)

6th Grade	9th Grade	12th Grade
1 ○	1 ○	1 ○
2 ○	2 ○	3 ○
3 ○	3 ●	4 ●
4 ●	4 ●	5 ○
5 ●	8 ○	8 ●
6 ○	9 ○	12 ●
7 ○	10 ●	
8 ●	11 ○	
9 ●	12 ○	
10 ○	17 ●	
	19 ●	

Vocabulary

Sleeve bearing
Shaft
Shavings
Nickel alloy
Drill bit

Learning Activity 1

Materials for Each Group of 2-4 Learners

Variable speed drill
Assorted metal drill bits
Thermometer
50 ml graduated cylinder (or small, narrow container)
Water
Assorted kinds of wood (approximately 2″ x 4″)

Procedure

Have learners discover for themselves how friction is created and what factors affect the amount of friction in a system by doing the following. Learners should document their actions and draw conclusions on Worksheet 4.21.

1. Fill a graduated cylinder or other small, narrow container with water.
2. Measure the temperature of the water. Record the temperature on the Worksheet 4.21.
3. Select a piece of wood; record the type of the wood on the worksheet.
4. Select a drill bit. Record its size on the worksheet.
5. Drill a hole in the wood. Record on the worksheet the depth of the hole and the amount of drill time.
6. Submerse the drill bit in the container of water. (The heat from the drill bit will be transferred to the water.)
7. Measure the temperature of the water. Record the temperature on the worksheet.
8. Subtract the temperature of the water before drilling from the temperature of the water after drilling. Record the difference in temperature on the worksheet.
9. Repeat the process with other types of wood, other drill bits, other drilled-hole depths, and other drill times.
10. Summarize your findings by answering the questions 1-4.

Learning Activity 2

Have learners observe the operation of machines with shafts that have sleeve bearings such as those found in machine shops. Have them identify sources of friction. Have them make suggestions for cutting down on friction during operation.

Thermodynamics Problem 4.2 Worksheet 4.21

Type of Wood	Size of Drill Bit	Depth of Hole	Length of Time Hole Was Drilled	Temperature of Water Before Drilling	Temperature of Water After Drilling	Difference in Temperature

Questions

1. What conditions made the drill bit the least hot?

2. What conditions made the drill bit the hottest?

3. In your own words, describe what friction is.

4. Explain how friction in machinery can be kept at a minimum.

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Problem

While running a machine, the operator notices that the bronze shaft gets hot at the same time every day. The operator also notices a pile of shavings under the stainless steel sleeve bearing every day. It is your job to determine why the shaft is overheating.

Identify the Problem

1. What is your job?
   A. To determine whether the belt is slipping
   B. To determine whether the bearing is too large for the shaft
   C. To check to see if the shaft is overheating
   D. To check to see if the shaft is made of a nickel alloy
   E. To check the temperature of the machine

Define the Problem

2. To begin to solve the problem, it would be BEST to:
   A. Check the rpm on the shaft.
   B. Check to see if the bearing is lubricated.
   C. Disassemble the machine to compare the bearing's diameter to the dimensions noted for items on the parts list.
   D. Check the v-belt width against the specifications on the parts list.
   E. Measure the air temperature near the machine.

Explore Alternatives

3. Which plan of action would BEST determine the cause of the shaft overheating?
   A. If the shaft is too hot, check to see if the machine is close to the heater.
   B. If the belt is not hot, check to see if the shavings are of the same material as the flywheel.
   C. If the shaft and the flywheel are hot and the belt is cool, the belt could be slipping.
   D. If the shaft and the bearings are hot, check to see what material the shavings are made of.
   E. If the shaft is too hot, check to see if the belt is broken.

Act on a Plan

4. The next logical step to a more permanent solution would be to
   - A. Tighten the belt.
   - B. Replace the belt.
   - C. Replace and lubricate the bearing.
   - D. Lubricate the existing bearing and start up the machine again.
   - E. Lubricate the belt.

Look at the Result

5. To see if the problem has been solved, you should restart the machine and
   - A. Check to see if the shaft and bearings stay cool.
   - B. Listen for squeaky belts.
   - C. Listen for a rattling flywheel.
   - D. Check to see if the temperature of the belt stays cool.
   - E. Check the temperature of the room near the machine.

Answers

1. C
2. B
3. D
4. C
5. A

Instructor's Notes:

Instructional Support Materials

Fluid dynamics

Fluid Dynamics Problem 4.3: Garden Water Hose

Scientific Principle

The relationship between fluid flow and resistance; as resistance increases, fluid flow decreases. A hose with larger size, shorter length, and fewer restrictions will result in the fastest flow.

Background

This principle was chosen because of its many workplace applications, including the following:

Fire fighting
Medical and intravenous drips
Irrigation
Application of pesticides and insecticides
Cooling systems
Paint-spraying systems
Welding systems (e.g., oxyacetylene)
Drinking water systems

Key Process Skills

(Refer to p. 24 for a description of each process skill.)

●	Observing
●	Communicating
●	Comparing
○	Ordering
●	Making models
●	Measuring
●	Recording
●	Interpreting data
●	Experimenting
●	Predicting
○	Hypothesizing
●	Inferring
●	Categorizing or classifying
●	Recognizing relationships
●	Controlling variables

Ohio Science Proficiency Outcomes

(Refer to Appendix D, pp. 335-337, for a description of each outcome.)

6th Grade	9th Grade	12th Grade
1 ●	1 ●	1 ○
2 ●	2 ●	3 ○
3 ●	3 ●	4 ○
4 ○	4 ●	5 ○
5 ●	8 ●	8 ○
6 ○	9 ○	12 ●
7 ○	10 ○	
8 ○	11 ○	
9 ○	12 ○	
10 ○	17 ○	
	19 ○	

Vocabulary

Fluid flow
Resistance
Diameter

The instructor may provide some or all of the following experiences to help learners gain an understanding of how to solve fluid dynamics problems.

Learning Activity 1

The Effect of Hose Diameter Upon Flow Rate

Materials for Each Group of Learners

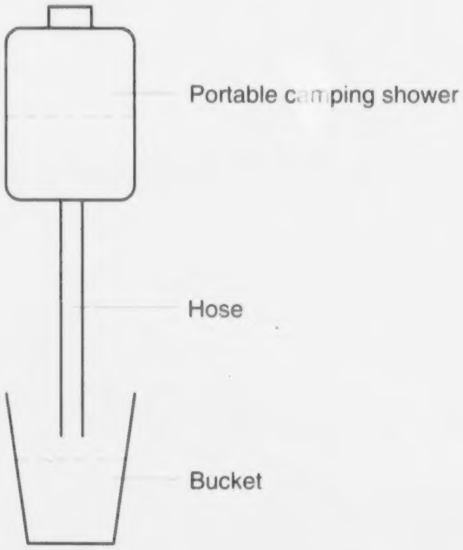
Portable camping shower (found in sporting goods stores for less than $10)
Several diameters of aquarium hose to attach to the shower outlet (e.g., 3/8″, 1/2″, and 5/8″) (found in large hardware stores)
5-gallon bucket to catch water
Cotton balls
Stopwatch or clock to measure the time of flow

Background

Different diameters of hoses cause different flow rates due to their different degrees of resistance. Hoses with smaller diameters have greater resistance to flow than do hoses with larger diameters. In addition, kinks cause changes in rates of flow in hoses.

Procedure

Either conduct a demonstration or instruct learners to do the following activities that will help them to determine how obstructions in hoses affect the flow rate. Use the following diagram to guide the learning activities. Have learners record their findings on Worksheet 4.3.



Before beginning the experiments described below, have learners predict which hoses will provide the quickest flow.

Trial 1: Measure how long it takes to empty an equal volume of water using different sizes of hoses (e.g., 3/8", 1/2", and 5/8" in diameter). Record your findings on Worksheet 4.3.

Trial 2: Make kinks in each hose. Then measure how long it takes to empty an equal volume of water using all 3 diameters of hose. Record your findings on the worksheet.

Trial 3: Stuff a cotton ball in each hose. Then time how long it takes to empty an equal volume of water using all 3 diameters of hose. Record your findings on the worksheet.

Trial 4: As a summarizing activity, have learners answer the questions on the worksheet. Then have them compare the flow rates they found in Trials 1-3. Facilitate a discussion of their findings and help learners draw conclusions.

Fluid Dynamics Problem 4.3

Worksheet 4.3

Before beginning each trial, make a prediction about which size of hose will allow the liquid to flow through the quickest. Explain.

	Flow Rate of 3/8" Hose	Flow Rate of 1/2" Hose	Flow Rate of 5/8" Hose	Flow Rate of Other Hoses
Trial 1: Unobstructed Hose				
Trial 2: Kinked Hose				
Trial 3: Hose Obstructed With a Cotton Ball				

Questions

1. In each trial, which hose size caused the liquid to flow through the quickest?

2. In each trial, which hose caused the liquid to flow through the most slowly?

3. Why was the flow of fluids quicker when using some hoses as opposed to others?

4. What conclusions can you draw about flow and resistance?

5. When designing and adjusting machines, why would a knowledge of flow and resistance be important?

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Problem

You are asked to water the garden at the back of the building. The 50-foot, 3/4″-diameter hose you have is too short. You added a section of 50-foot, 1/2″-diameter hose with a coupler. You then adjusted the faucet at the house so that it is fully open. No water flows from the hose.

Identify the Problem

1. What is your assignment?
   - A. To add another length of hose
   - B. To decide on the amount of water needed for the garden
   - C. To get a larger diameter hose
   - D. To restore water flow to enable you to water the garden
   - E. To measure the total length of hose needed to reach the garden

Define the Problem

2. What is the FIRST step to gain water flow?
   - A. Call the plumber.
   - B. Find a cause for the lack of water flow.
   - C. Add more hose.
   - D. Remove a hose.
   - E. Turn off the valve.

Explore Alternatives

3. Which of the following would NOT be a possible cause for the lack of water flow?
   - A. Defective nozzle
   - B. Kinks in a hose
   - C. Dirt or other debris in one of the hoses
   - D. A large hole in one of the hoses
   - E. The large diameter of the hose

Act on a Plan

4. What step should be taken FIRST?
   - A Replace the hose.
   - B. Look for obstructions.
   - C. Adjust the water faucet.
   - D. Call the plumber.
   - E. Elevate the hose.

Look at the Result

5. You found a kink in the hose and straightened it. What should be your NEXT step?
   A. Squeeze the nozzle.
   B. Adjust the faucet.
   C. Pay the plumber.
   D. Disconnect the hose.
   E. Check the connections for tightness.

Answers

1. D
2. B
3. E
4. B
5. A

Instructor's Notes:

Instructional Support Materials

Fluid dynamics

Fluid Dynamics Problem 4.4: Car Brakes

Scientific Principle

Pascal's law; pressure applied to an enclosed fluid is transmitted equally in all directions to every portion of the fluid and to the walls of the container.

Background

In this problem, learners will examine several possible causes for brake failure and identify the most likely cause given a specific set of variables. Learners will solve problems concerning one of the mechanical properties of fluids.

Key Process Skills

(Refer to p. 24 for a description of each process skill.)

●	Observing
●	Communicating
●	Comparing
○	Ordering
○	Making models
○	Measuring
○	Recording
○	Interpreting data
○	Experimenting
●	Predicting
○	Hypothesizing
●	Inferring
○	Categorizing or classifying
●	Recognizing relationships
○	Controlling variables

Ohio Science Proficiency Outcomes

(Refer to Appendix D, pp. 335-337, for a description of each outcome.)

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6 ○	9 ○	12 ●
7 ○	10 ○	
8 ○	11 ○	
9 ○	12 ○	
10 ○	17 ●	
	19 ●	

Vocabulary

Pressure
Hydraulics
Brake system (e.g., brake lines, brake pedal, brake shoes)
Pressure gauge

Learning Activity

Materials

Diagram of hydraulic brake system (Diagram 4.41)
Hydraulic brake system from automobile, if available. If this is not available, make the following substitutions:

Substitute	**For**
3-foot rubber hose	brake lines
water	brake fluid
syringe	brake pedal
pressure gauge	movement of brake shoes

Attach the syringe to one end of the hose and the pressure gauge to other end. Then, fill the hose with water and compress the syringe. When compressed, pressure will be placed on the water in the hose, which will, in turn, place pressure on the pressure gauge. This simulates the action in a brake system when the brake pedal is depressed. That is, placing pressure on the brake fluid in the lines results in pressure on the brake shoes.

Procedure

1. Show learners a diagram of a hydraulic brake system. (Use Diagram 4.41 if you wish.) Ask them to explain (or make an educated guess about) how the brake system works.
2. Have learners operate the brake pedal on a properly functioning brake system.
3. Then, cause a leak in the brake system by loosening a brake line.
4. Have learners operate the brake pedal again—to compare the feel of a functioning brake to that of a non-functioning brake system.
5. Have learners visually inspect the brake shoes while a classmate pumps the brakes. This will enable them to see that the brakes are not being activated when the brakes are not functioning.
6. Facilitate a discussion with learners about what they observed and experienced. Have learners generalize how brake systems work and what causes them to malfunction.

   Point out that Pascal's law is at work—forcing the brake fluid out of the unsealed chamber. (In the absence of a leak, the fluid would apply force to the brake shoes.)
7. Have learners summarize how a brake system works, either orally to a classmate or in writing. Have them describe how they would repair a malfunctioning brake system.

Problem

You are driving your car north on a interstate highway at a speed of 57 miles per hour. As you prepare to exit, you depress the brake pedal to slow the car down. The pedal goes to the floor, and the car does not slow down. You steer to the berm as you quickly pump the brakes 8-10 times, and the car gradually begins to slow down. To stop the vehicle, you apply the emergency brake and the car eventually stops. What will you do to solve the problem before getting on the road again? Refer to Diagram 4.41 to answer the questions that follow.

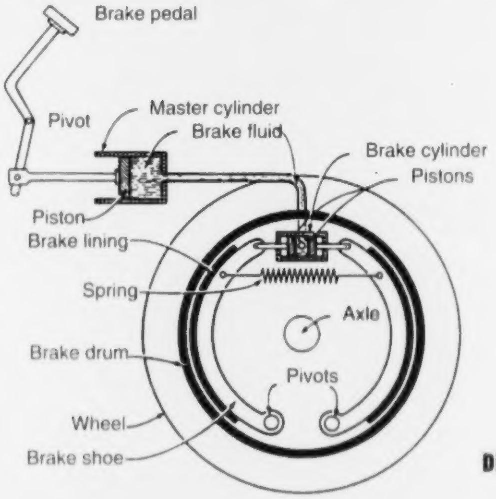

Diagram 4.41

This diagram was reproduced by permission of Delmar Publishers, Albany, NY. It was taken from *Introduction to Applied Physics*, Second Edition (1985) by Marcus and Thrower.

Identify the Problem

1. What is the problem?
   - A. The brake pedal is too small to stop the movement of the car.
   - B. You were not driving at the posted speed limit.
   - C. You must have taken the wrong exit.
   - D. The brakes were not working properly.
   - E. The road was too wet.

Define the Problem

2. Why did the car eventually stop?
   - A. It ran out of gas.
   - B. Although the hydraulic brake system failed, the emergency brake worked.
   - C. The hydraulic brake system was in working order, but the emergency brakes failed.
   - D. The car was going uphill.
   - E. The car needs to use two braking systems instead of one in order to stop.

Explore Alternatives

3. Which system is most likely to have failed, preventing the car from stopping when the brake pedal was applied?
   A. Brake shoes
   B. Wheels
   C. Brake drum
   D. Brake fluid
   E. Battery

4. Although the brake pedal was pumped, the vehicle did not stop as expected. Why would pumping the brake pedal begin the process of slowing the vehicle, but not cause it to stop as normally expected?
   A. The tires on the vehicle are worn and need to be replaced.
   B. The road conditions do not allow for proper stopping of vehicles.
   C. A leak has developed in the brake line(s).
   D. The brake pedal is an incorrect size for the size of the vehicle.
   E. You lack the strength to properly press on the brake pedal initially, causing a need for pumping.

Act on a Plan

5. For what reason is it important to know where the leak in a hydraulic brake system is located?
   A. You must determine which parts to order from the parts manager.
   B. Unless you determine the source of the fluid escape, you cannot restore the system to its properly closed function.
   C. Brake fluid might collect in places that are not the source of the leak.
   D. All of the above are correct.
   E. None of the above are correct.

Look at the Result

6. The leak has been discovered and repaired in a malfunctioning hydraulic brake system. Before driving the vehicle, what should take place?
   A. The vehicle should be thoroughly washed to remove any brake fluid from the car's finish.
   B. The seat should be readjusted to compensate for the change in brake pedal position, if any.
   C. With the wheels removed, have pressure applied to the brake pedal while observing the brake shoes and pads to ensure their proper activation.
   D. Drive the vehicle at a slow speed in an open area to be sure it isn't damaged.
   E. With the wheels removed, drive the vehicle at a slow speed in an open area while observing the brake shoes and pads to ensure their proper activation.

Answers

1. D
2. B
3. D
4. C
5. B
6. C

Instructor's Notes:

Wall switch
Electricity
110 V Outlet

Electricity Problem 4.5: Three-Way Light Switch

Scientific Principle

Basic principles of electricity, including Ohm's law (e.g., the relationship between pressure, current flow, and resistance in an electrical system).

Background

Electrical problems provide a wide variety of opportunities for learners to practice diagnosing electrical systems and solving problems within those systems.

Key Process Skills

(Refer to p. 24 for a description of each process skill.)

●	Observing
●	Communicating
●	Comparing
◐	Ordering
◐	Making models
◐	Measuring
●	Recording
◐	Interpreting data
●	Experimenting
●	Predicting
◐	Hypothesizing
●	Inferring
◐	Categorizing or classifying
●	Recognizing relationships
◐	Controlling variables

Ohio Science Proficiency Outcomes

(Refer to Appendix D, pp. 335-337, for a description of each outcome.)

6th Grade	9th Grade	12th Grade
1 ◐	1 ◐	1 ◐
2 ●	2 ●	3 ◐
3 ●	3 ●	4 ●
4 ◐	4 ◐	5 ◐
5 ●	8 ◐	8 ◐
6 ◐	9 ◐	12 ●
7 ◐	10 ●	
8 ◐	11 ◐	
9 ●	12 ●	
10 ●	17 ●	
	19 ●	

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Electricity Problem 4.5

Vocabulary

Power source
Circuit
Electron

In electricity Problem 3.6, several suggestions were made for providing learners with opportunities to learn about the basic principles of electricity. The following learning activity focuses participants on solving electrical problems.

Learning Activity

Materials

Diagrams of a variety of circuits
A variety of battery/light circuits
A basic electricity lab setup, such as the Principles of Technology electrical labs on series and parallel circuits (helpful but not necessary)

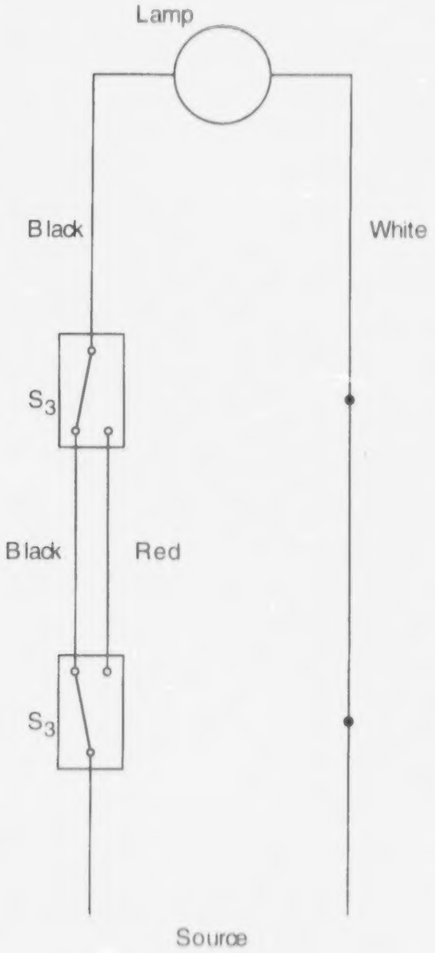
Procedure

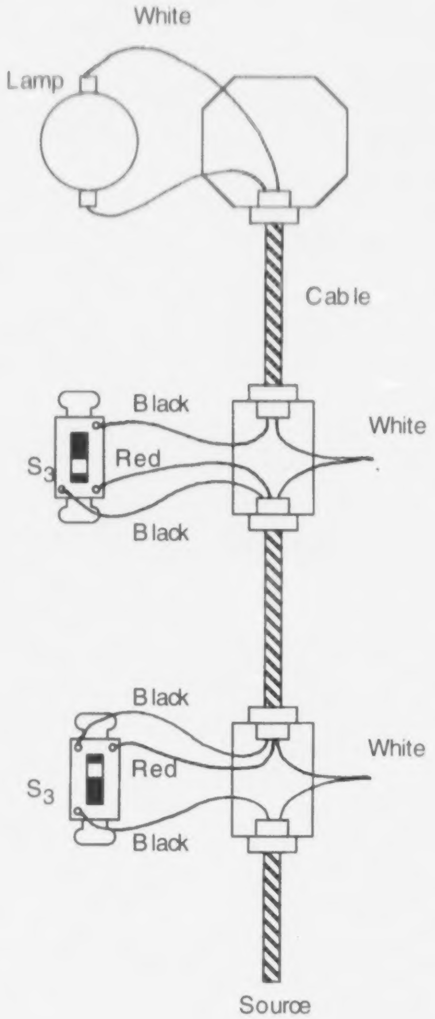
1. Facilitate a discussion with learners to review the elements of a complete circuit (e.g., power source, load, completed circuit). Reinforce that electrons follow the path of least resistance (Ohm's law).
2. Ask learners to describe examples of three-way circuits (e.g., conveyer switches, a light in a garage, a light over a stairway). Have them draw a diagram of a three-way circuit.
3. Have learners trace various circuit diagrams to see if they depict complete circuits.
4. Give learners circuits with bad components and ask them to identify the defective components.

Problem

Upon returning home late one evening, you flip the three-way light switch at the bottom of your stairway. The light comes on as it was designed to and you proceed up the stairs. When you reach the top of the stairway and try to turn the light off by flipping the other three-way switch; the light will not turn off. You need to figure out what is wrong.

Refer to the diagram below to answer the questions that relate to this problem.


Lamp
Black
White
S_3
Black
Red
S_3
Source


White
Lamp
Cable
Black
S_3
Red
Black
White
Black
S_3
Red
Black
White
Source

Identify the Problem

1. What is the problem?
   A. The light does not turn on with either switch.
   B. The light does not turn on with the switch at the top of the stairs.
   C. The light does not turn on with the switch at the bottom of the stairs.
   D. The light turns on only when in the "down" position.
   E. The light always stays on.

Define the Problem

2. Where is the MOST PROBABLE location of the problem?
   A. The lightbulb
   B. The switch at the bottom of the stairs
   C. The switch at the top of the stairs
   D. The wiring running between the switches
   E. A blown fuse

3. The statement that best describes the defective circuit is:
   A. The switch at the bottom of the stairs lacks power.
   B. The switch at the top of the stairs lacks power.
   C. The lightbulb is bad.
   D. The switch at the top of the stairs is bad.
   E. The switch at the bottom of the stairs is bad.

Explore Alternatives

4. When the switch at the bottom of the stairs is turned to the on position, you would expect the switch at the top of the stairs to operate the light
   A. Normally in both positions.
   B. On only in both positions.
   C. Off only in both positions.
   D. On in the "up" position only.
   E. On in the "down" position only.

Act on a Plan

5. To repair the light, one should plan to
   - A. Replace the lightbulb.
   - B. Replace the switch at the top of the stairs.
   - C. Replace the switch at the bottom of the stairs.
   - D. Replace the fuse.
   - E. Rewire between the switches.

Look at the Result

6. After the switch at the top of the stairs is replaced with a new switch, it is likely that the light will
   - A. Operate normally.
   - B. Remain on all the time.
   - C. Remain off all the time.
   - D. Operate normally only when the switch at the bottom of the stairs is on.
   - E. Operate normally only when the switch at the bottom of the stairs is off.

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Answers

1. B
2. C
3. D
4. C
5. B
6. A

Instructor's Notes:

Electricity Problem 4.6: New Home Amps

Scientific Principle

Basic principles of electricity, including Ohm's law (e.g., the relationship between pressure, current flow, and resistance in an electrical system).

Background

A *series circuit* has only one path for current (as shown in Diagram 4.61). A *parallel circuit* has more than one path (as shown in Diagram 4.62). For *current* to flow, a circuit must be continuous. In a parallel circuit, the total circuit current is the sum of the currents through the individual paths. A *resistor*, also known as a load, is anything that slows down the flow of current. A *circuit breaker* is a safety device that turns the circuit off if the allowable amount of current is exceeded.

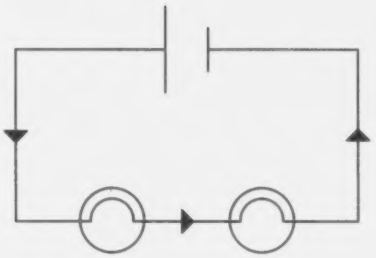

Diagram 4.61.

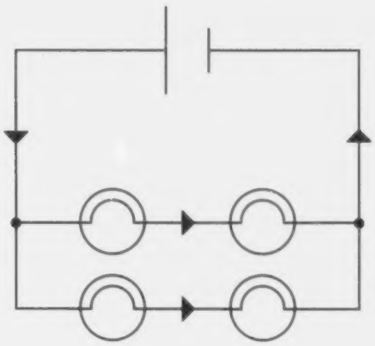

Diagram 4.62

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Key Process Skills

(Refer to p. 24 for a description of each process skill.)

●	Observing
●	Communicating
●	Comparing
◐	Ordering
●	Making models
●	Measuring
◐	Recording
●	Interpreting data
●	Experimenting
●	Predicting
◐	Hypothesizing
●	Inferring
◐	Categorizing or classifying
●	Recognizing relationships
●	Controlling variables

Ohio Science Proficiency Outcomes

(Refer to Appendix D, pp. 335-337, for a description of each outcome.)

6th Grade	9th Grade	12th Grade
1 ●	1 ●	1 ◐
2 ●	2 ●	3 ◐
3 ●	3 ●	4 ●
4 ●	4 ●	5 ◐
5 ●	8 ◐	8 ◐
6 ◐	9 ◐	12 ●
7 ◐	10 ●	
8 ◐	11 ◐	
9 ◐	12 ◐	
10 ◐	17 ●	
	19 ●	

Vocabulary

Circuit
Current
Resistor or load
Amp
Circuit breaker
Parallel circuit
Series circuit

Learning Activity 1

Materials for Each Pair of Learners

8 pieces of coated copper wire
1 battery
3 flashlight bulbs
Volt meter

Procedure

1. Distribute Worksheet 4.61 to learners. Have them work individually or in pairs to set up a simple parallel circuit using either house current or a direct current source (e.g., battery) depending on the supplies available; coated copper wires; and three lightbulbs.
   A. Instruct learners to disconnect one bulb. Have them observe what happens to the other two bulbs.

   Answer: They stay on.

   B. Have learners reconnect the bulb. Have them disconnect the wire at Point 1. Have them observe what happens to the bulbs and record their observations.

   Answer: All three go off.

   Relate to the idea that a fuse or circuit breaker placed between the power source and Point 1 would protect the entire circuit.

   C. Have learners measure voltages and/or currents at various points in the circuit. Have them record generalizations that they make from this activity.

   Answer: Voltage at any point in the circuit should be the same. Current in the main circuit equals the sum of currents in each path.

2. Distribute Worksheet 4.62.
   A. Ask learners to calculate the total current for the parallel circuit.

      Answer: 1.6 amp

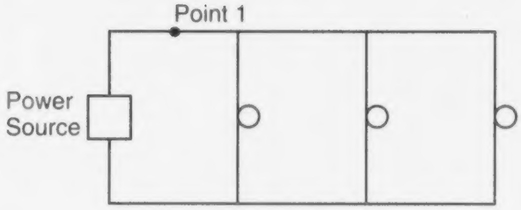
   B. Ask learners to calculate the total current when another 10-Ohm resistor is added in parallel to the circuit.

      Answer: Current in the new branch is 1 amp; the total current is 2.6 amp.

   C. Ask learners to place a third 10-Ohm resistor in parallel to the circuit. Have them explain their answer to the class or a classmate.

      Answer: This would add another 1 amp, giving a total of 3.6 amps. The 3 amp fuse would blow and the circuit would no longer work.

Worksheet 4.61



1. Set up a simple parallel circuit according to the diagram above. Use either house current or a direct current source (e.g., battery) depending on the supplies available; coated copper wires; and three lightbulbs.

2. Disconnect one bulb. Observe what happens to the other two bulbs. Record your observation.

3. Reconnect the bulb. Disconnect the wire at Point 1. Observe what happens to the bulbs. Record your observations.

4. Predict what would happen if a fuse or circuit breaker was placed between the power source and Point 1. Write your prediction in the space provided.

5. Measure voltages and/or currents at various points in the circuit. Does the voltage vary at different points in the circuit? Explain.

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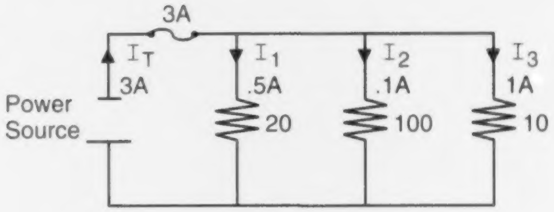
Worksheet 4.62



1. With your finger, follow the flow of electricity through the circuit above.

2. Is it a parallel or a series circuit? Explain.

3. Calculate the total current for the circuit.

4. Calculate the total current when another 10-Ohm resistor is added in parallel to the circuit.

5. What will happen if a third 10-Ohm resistor be placed in parallel to the circuit? Write your answer in the following space. Then explain your answer to a classmate.

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Problem

You have moved into a new home. You are experiencing difficulty with the electrical system and the heating system. The 20-amp circuit breaker has been reset three times in one day. The washer, the television, and the space heater are currently in use with no problem. You are attempting to add more appliances. Below is a table listing all of the items on this circuit.

Appliance	Amps
Computer	2
Hair dryer	12
Clock	25
Vacuum	4
Stove	10
Stereo	2
Toaster	10
Washer	4
Lightbulb	.5
Space heater	8
Television	3

You need to determine which of the following two additional appliances can be used without tripping the breaker.

○ Toaster and lightbulb

○ Stereo and computer

○ Stereo and vacuum

○ Hair dryer and clock

Identify the Problem

1. What is your assignment?
   A. To turn down the furnace
   B. To determine why the washing machine throws the circuit breaker
   C. To determine which additional electrical appliances can be used in the circuit without throwing the circuit breaker
   D. To realize that the temperature outside is 32 degrees Fahrenheit
   E. To turn down the stereo

Define the Problem

2. What do you need to consider to solve this problem?
   A. The maximum allowable amperage for this parallel circuit
   B. The number of outlets in your home
   C. The size of the furnace
   D. The television is black-and-white or color
   E. The voltage of the circuit

Explore Alternatives

3. What is the BEST way to solve this problem?
   A. Try all combinations by doing calculations.
   B. Replace the circuit breaker.
   C. Never use your space heater.
   D. Call a repair person.
   E. Try all combinations by using trial and error.

Act on the Plan

4. What is the correct combination of appliances?
   A. Toaster and lightbulb
   B. Stereo and computer
   C. Stereo and vacuum cleaner
   D. Hair dryer and clock
   E. None of the above combinations is correct

Look at the Result

5. Is the new total less than or equal to 20 amps?
   A. Yes
   B. No

Answers

1. C
2. A
3. A
4. B
5. A

Instructor's Notes:

Instructional Support Materials

Electricity Problem 4.7: **Pan Conveyor Motor**

Scientific Principle

Basic principles of electricity, including Ohm's law (e.g., the relationship between pressure, current flow, and resistance in an electrical system).

Background

Electrical problems provide a wide variety of opportunities for learners to practice diagnosing electrical systems and solving problems within those systems.

Key Process Skills

(Refer to p. 24 for a description of each process skill.)

●	Observing
●	Communicating
●	Comparing
○	Ordering
○	Making models
○	Measuring
○	Recording
○	Interpreting data
○	Experimenting
●	Predicting
○	Hypothesizing
●	Inferring
○	Categorizing or classifying
●	Recognizing relationships
○	Controlling variables

Ohio Science Proficiency Outcomes

(Refer to Appendix D, pp. 335-337, for a description of each outcome.)

6th Grade	9th Grade	12th Grade
1 ○	1 ○	1 ○
2 ○	2 ●	3 ○
3 ●	3 ○	4 ●
4 ○	4 ○	5 ○
5 ●	8 ○	8 ○
6 ○	9 ○	12 ○
7 ○	10 ●	
8 ○	11 ○	
9 ●	12 ○	
10 ●	17 ○	
	19 ○	

Instructional Strategies

The principles addressed in this problem are similar to those of Problems 4.5 and 4.6. The same instructional strategies apply to each of the Level 4 electrical problems.

Problem

An operator is attempting to start up Production Line 7. He clicks on the "start" button for the pan conveyor and nothing happens. He notices that there is a message in the alarm window that reads "Pan conveyor motor fault." What should the operator do to investigate and resolve the problem?

NOTE: There is not a diagram of the pan conveyor system that is involved in this problem. Learners are encouraged to draw a diagram that represents such a system. (In a pan conveyor system, a motor causes the conveyor to vibrate. The conveyor vibrates to move raw materials from one point to another in the production process.)

Identify the Problem

1. What piece of equipment is the operator having problems with?
   - A. The pan conveyor
   - B. A motor overload for the pan conveyor motor
   - C. The computer and the PLC
   - D. The Acrison® feeders
   - E. None of the above

Define the Problem

2. The statement that best describes the operator's problem is:
   - A. The pan conveyor will not start.
   - B. None of the feeders will run.
   - C. The extruder will not start.
   - D. The "start" button malfunctioned.
   - E. None of the above occurred.

Explore Alternatives

3. What is the most likely cause of the problem?
   - A. A burned-up drive motor
   - B. A tripped motor overload
   - C. Too much material on the pan conveyor
   - D. Improperly wired motor circuit
   - E. None of the above

Act on the Plan

4. The operator should:
   - A. Call his or her supervisor for advice.
   - B. Call maintenance to check out the problem.
   - C. Check the motor starter to see if the overload is tripped; if so, reset it.
   - D. Acknowledge the alarm and try to start the conveyor again.
   - E. Do none of the above.

Look at the Result

5. Once the problem has been corrected, how can it be avoided in the future?
   - A. Notify maintenance of what happened and have them check the overload settings.
   - B. Know what caused the overload to trip.
     Have maintenance wire the motor correctly.
   - C. Do both A and B.
   - D. Do none of the above.

Answers

1. A
2. A
3. B
4. C
5. D

Instructor's Notes:

Instructional Support Materials

Mechanics Problem 4.8: Lawn Mower Valves

Scientific Principle

Torque, which involves center of mass, balance, and rotational movement

Background

This principle has a wide variety of applications including wheel rotation, machining operations, sawing, and any technical systems that rotate (e.g., motor shafts, fans, airplane propellers, and turbine blades).

Torque is an important concept in understanding balance. There is a moment arm and a hanging weight. When the hanging weight is farther from the pivot point, the torque is greater. The pivot point is the center of the system's mass when the system is in balance.

The torque on each side of the *pivot point* has to be equal. This is an example of the old teeter totter problem. A heavy weight needs to be moved closer to the pivot point to get less torque, while a lighter weight has to be moved farther away from the pivot point to get greater torque.

Key Process Skills

(Refer to p. 24 for a description of each process skill.)

●	Observing
●	Communicating
●	Comparing
○	Ordering
●	Making models
○	Measuring
●	Recording
●	Interpreting data
●	Experimenting
●	Predicting
●	Hypothesizing
●	Inferring
○	Categorizing or classifying
●	Recognizing relationships
○	Controlling variables

Ohio Science Proficiency Outcomes

(Refer to Appendix D, pp. 335-337, for a description of each outcome.)

6th Grade	9th Grade	12th Grade
1 ●	1 ○	1 ○
2 ○	2 ●	3 ○
3 ●	3 ●	4 ●
4 ○	4 ●	5 ○
5 ●	8 ○	8 ○
6 ○	9 ○	12 ○
7 ○	10 ○	
8 ○	11 ○	
9 ○	12 ○	
10 ○	17 ○	
	19 ○	

Vocabulary

Torque
Pivot point
Center of mass
Balance
Rotation

The instructor may present some or all of the following experiences to give learners practice in solving mechanical problems. In the first activity, learners work together in groups to learn about the principles involved in balance. Their first assignment is to place weights on each end of a yardstick until balance is achieved. In the second activity, learners discover what happens when a fan system is out of balance. By placing a weight on one of the fan blades, learners see for themselves what happens when a system is out of balance. In the third activity, learners synthesize what they learned by constructing a mobile.

Worksheet 4.8, which follows Learning Activity 3, may be used to record observations made during each activity in this section.

Learning Activity 1

Balance Beam

Materials for Each Group of Learners

A metal yardstick (Drill one or more holes that are large enough through which to insert a nail as a pivot point so the yardstick can freely pivot.)
Clothespins or other items that can be used as weights

Procedure

1. Divide the class into small groups.
2. Instruct one person in each group to place a nail in one of the holes and to hold nail at the pivot point for the yardstick. Have other group members move the weights to produce "balance." By trial and error, learners can adjust various weights at different locations on each end of the yardstick until balance occurs. Have learners record their actions and observations on Worksheet 4.8.
3. After the first trial is completed, have someone else in the group place the nail in a different hole; repeat the process. Have learners record their actions and observations on Worksheet 4.8.

4. Have group members share their observations, discuss their findings, and draw conclusions. Have them each write a summary of what they learned about balance on Worksheet 4.8.
5. Have each group report its findings to the whole class. Record generalizations on the chalkboard or on newsprint.

Learning Activity 2

Out-of-Balance Fan Blades

Materials for Each Group of Learners

A fan with an electric motor, ideally with 2 or 3 speeds
A nut, a bolt, and a locknut washer sufficient to mount on a fan blade
A drill and bit to drill a hole in a fan blade
A Variac to control or change the motor's rpm speed (optional)
(NOTE: A Variac is a variable-speed motor controller)
Safety glasses

Procedure

1. Divide the class into small groups.
2. Have learners turn on the fan to observe how it operates when it is in balance.
3. Have the group members write a description of what they observed on Worksheet 4.8. Encourage them to include one or more diagrams.
4. Instruct learners to drill a hole in a blade of the fan and mount a bolt onto the blade.
5. Ask learners to predict what will happen when the fan is turned on.
6. Have them turn on the fan and observe what happens. Have learners record their actions, observations, and conclusions on Worksheet 4.8.
7. If the fan has a multispeed motor, or if a Variac is available, have learners run the out-of-balance fan at different speeds to observe what happens. They will see the effects of motor speed on vibration intensity.
8. Have group members write on Worksheet 4.8 a description of what they observed. Encourage them to include one or more diagrams.
9. Facilitate a class discussion about what was learned. Have learners define the principles involved in torque, which are balance, center of mass, and rotational movement.

Learning Activity 3

Construction of a Mobile

Materials for Each Group of Learners

6"-8" sections of dowel rod, with holes drilled at various positions
A variety of objects to hang on mobiles (e.g., washers, buttons, or other small objects that can be tied with string or cord)
String or cord
Scissors

Procedure

1. Have learners work individually or in pairs.
2. Instruct learners to construct a mobile that balances. They should hang objects from string or cord that is suspended from sections of dowel rod, so that *each piece of dowel rod balances on the supporting string.* The mobile should be a 3-tiered or 4-tiered system. Have learners record their actions and observations on Worksheet 4.8.
3. While learners are working on their mobiles, circulate around the room. To promote critical thinking and to encourage problem solving, ask learners open-ended questions, such as those listed on pp.17-19.
4. After the mobiles are completed, facilitate a discussion so that learners can summarize what they learned and draw conclusions from their experience.
5. Have learners give examples of how the principles involved in torque (i.e., balance, center of mass, and rotational movement) are used in everyday life. Examples include motor shafts, fans, airplane propellers, and turbine blades.
6. Have learners write a summary of what they learned on Worksheet 4.8. Encourage them to draw diagrams to accompany their written description.
7. Facilitate a class discussion about what was learned. Be sure that the concepts of balance, center of mass, and rotational movement are discussed.

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Mechanics Problem 4.8

Worksheet 4.8

Observations About Balance

Team Members' Names ____________________

What We Did	What We Observed	Explanation

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Problem

You own a lawn mower service and use a 13-hp riding lawn mower with twin cutting blades mounted under a 42″ deck. The engine powers the blades by use of a belt-and-pulley system, which includes a clutch that can be engaged when desired. You just finished mowing a lawn with some rough terrain. You transport the riding lawn mower to the next job. Upon arriving at the next site, you start the engine. The motor starts easily and runs smoothly. Upon engaging the cutting blades, you notice some unusual and excessive vibration but not any unusual noises. The vibration increases in intensity as you increase the engine speed. You need to determine the cause of this unwanted vibration. Refer to diagram 4.81 to answer the following questions.

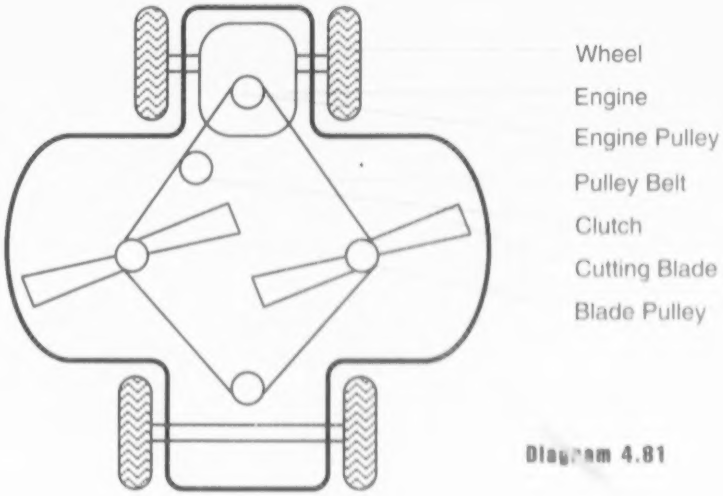


Diagram 4.81

Identify the Problem

1. What is your assignment?
   A. Continue to mow the lawn.
   B. Accelerate the engine.
   C. Decelerate the engine.
   D. Find the cause of the vibration.
   E. Disengage the blade and continue.

Define the Problem

2. When did the vibration start?
   - A. When you started the engine
   - B. When you sat down on the lawn mower's seat
   - C. When you transported the lawn mower between mowing sites
   - D. When you increased the engine speed
   - E. When you engaged the mower blades

Explore Alternatives

3. What is the most likely cause of the vibrations?
   - A. Bent engine crankshaft
   - B. Cutting deck
   - C. Loose tire mount
   - D. Low engine oil
   - E. Improperly engaged clutch

Act on a Plan

4. What should be done FIRST to eliminate the vibration?
   - A. Adjust the blade elevation.
   - B. Balance the blade.
   - C. Adjust the belt tension.
   - D. Visually inspect the underside of the mower deck for irregularities.
   - E. Sharpen the blades.

Look at the Result

5. You inspected the underside of the deck and found a bent cutting blade. What should you do next?
   - A. Replace the blade.
   - B. Sharpen the blade.
   - C. Lower the blade so that it doesn't hit the deck housing.
   - D. Lubricate all of the bearings.
   - E. Adjust the tension in the drive belt.

Mechanics Problem 4.8

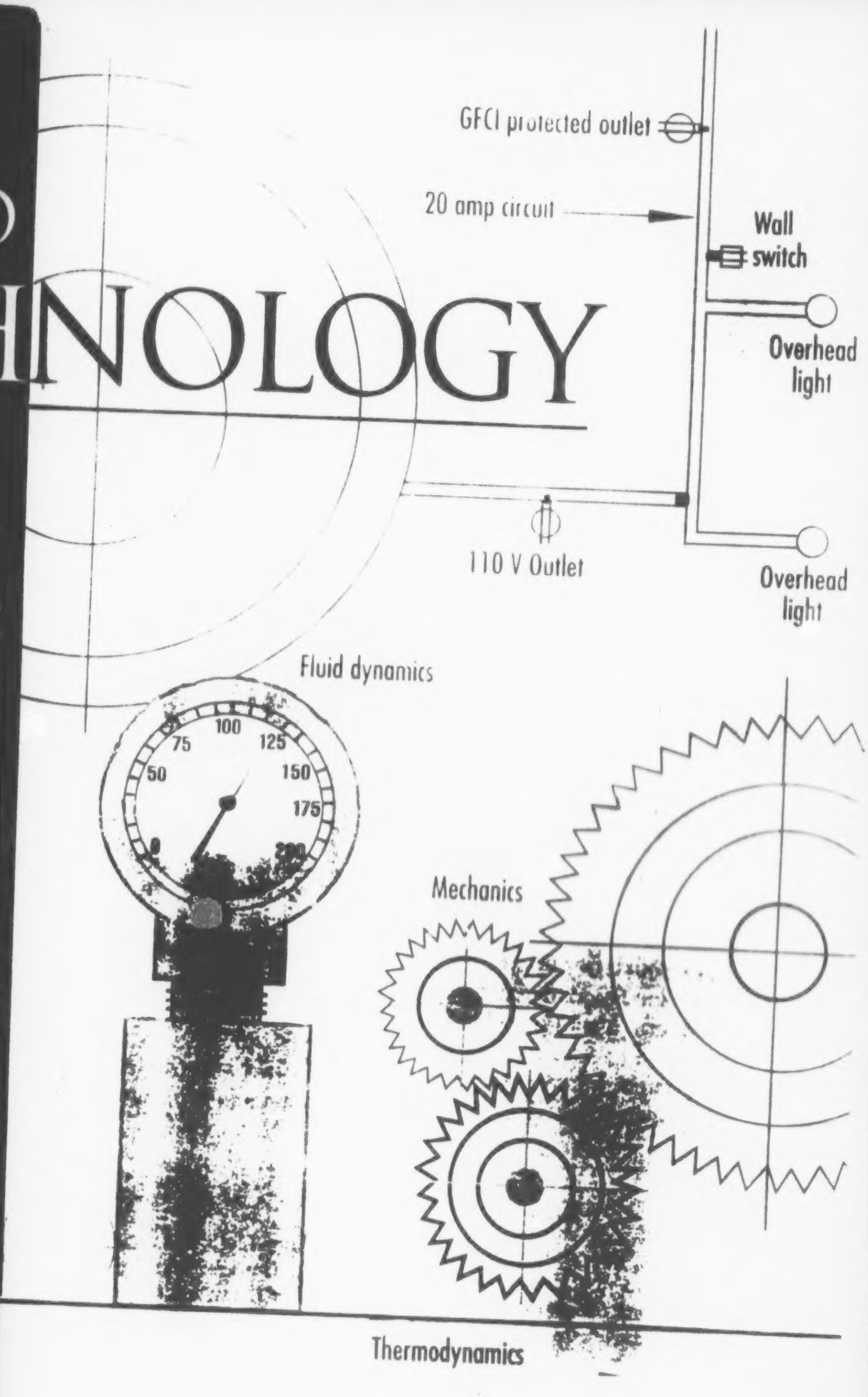
Answers

1. D
2. E
3. B
4. D
5. A

Instructor's Notes:

APPLIED TECHNOLOGY

TARGETS FOR LEARNING


GFCI protected outlet
20 amp circuit
Wall switch
Overhead light
110 V Outlet
Overhead light
Fluid dynamics
75
100
125
50
150
175
0
200
Mechanics
Thermodynamics

LEVEL 5 LEARNING ACTIVITIES AND PROBLEMS

The learning activities and problems in this section are designed to help learners reach applied technology Level 5.

> *"These activities seemed to really bring some points home with students."*
>
> Pilot Instructor

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Improving to Level 5

As defined and measured by Work Keys, Level 5 learners can

- Use the basic principles of mechanics, electricity, fluid dynamics, and thermodynamics in moderate and advanced applications.
- Understand complex machines and systems (e.g., operation of gas engines, complex appliances, or an electrical system in a building).
- Solve problems that include a larger problem space, more extraneous information, and more technical terms than those at Level 4.
- Manipulate 2 or 3 variables within a system to solve a problem.
- Reduce the problem space to the point of knowing what to check first when inspecting a malfunctioning system or machine that could contain more than 10 potential sources of the problem.
- Evaluate multiple solutions to determine the best solution for each problem considering both the available resources and the needed resources.

The learning activities in this section are designed to help learners reach applied technology Level 5. In addition to presenting these, instructors may wish to use some of the books, software, and materials described in the Resource list, pp. 307-325, to—

- Gain a clearer understanding of the basic scientific principles involved in applied technology problems
- Select activities to supplement those in Targets for Learning
- Recommend resources to learners wishing to gain deeper insights about the basic scientific principles involved in applied technology problems

Improving to **Level 5** Index

Problem Number	Category	Problem Topic	Page Number
5.1	Thermodynamics	Office Cooling and Heating	191
5.2	Thermodynamics	Transformer Box Fans	199
5.3	Thermodynamics	Smog Hog	207
5.4	Fluid Dynamics	Mini-Oiler Air Line Lubricators	213
5.5	Electricity	Boat Trailer Lights	223
5.6	Electricity	Machine Indicator Lights	231
5.7	Mechanics	Lawn Mower Start-up	241
5.8	Mechanics	Truck Loading	247
5.9	Mechanics	Pellet-Transfer System	257

Thermodynamics Problem 5.1: **Office Cooling and Heating**

Scientific Principle

Several scientific principles are involved in this problem including air flow, resistance, equilibrium, and fluid pressure.

Background

Heating and cooling systems involve various devices including compressors, shutoff valves, thermostats, filters, ductwork and diffusers. The diffusers, which are usually in the ceiling, direct the air into the room.

As air passes over the radiator, it will be cooled by the water circulating in and out of the radiator, as shown in the diagram for Problem 5.1. The blower motor forces the air through the ductwork. Air valves (i.e., dampers) in each room are adjustable to regulate the airflow to each room. Since there is just one thermostat, which is set at 72° F, all rooms should be at that temperature. The *volume* of air delivered to each room will determine the actual room temperature. In the case of a cooling system, if airflow is too high, the room will be too cold; likewise air flow that is too low will cause a room to be too warm. In addition, a *low water level* in the radiator would affect all four rooms (as would a circuit breaker and blower system). Equilibrium is achieved when the airflow and resulting temperatures even out in all four rooms (within one degree).

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Key Process Skills

(Refer to p. 24 for a description of each process skill.)

○ Observing
● Communicating
○ Comparing
○ Ordering
● Making models
○ Measuring
○ Recording
● Interpreting data
● Experimenting
● Predicting
○ Hypothesizing
○ Inferring
○ Categorizing or classifying
● Recognizing relationships
○ Controlling variables

Ohio Science Proficiency Outcomes

(Refer to Appendix D, pp. 335-337, for a description of each outcome.)

6th Grade	9th Grade	12th Grade
1 ●	1 ○	1 ●
2 ○	2 ○	3 ○
3 ●	3 ○	4 ●
4 ○	4 ●	5 ○
5 ●	8 ○	8 ○
6 ●	9 ○	12 ●
7 ●	10 ●	
8 ○	11 ○	
9 ●	12 ○	
10 ○	17 ○	
	19 ○	

Vocabulary

Psi (pounds per square inch)
Cfm (cubic feet per minute)
Rpm (revolutions per minute)
Thermostat
Manometer
Pneumatic training materials
Flow-rate valve
Blower motor
Damper
Diffuser

Learning Activity

Materials

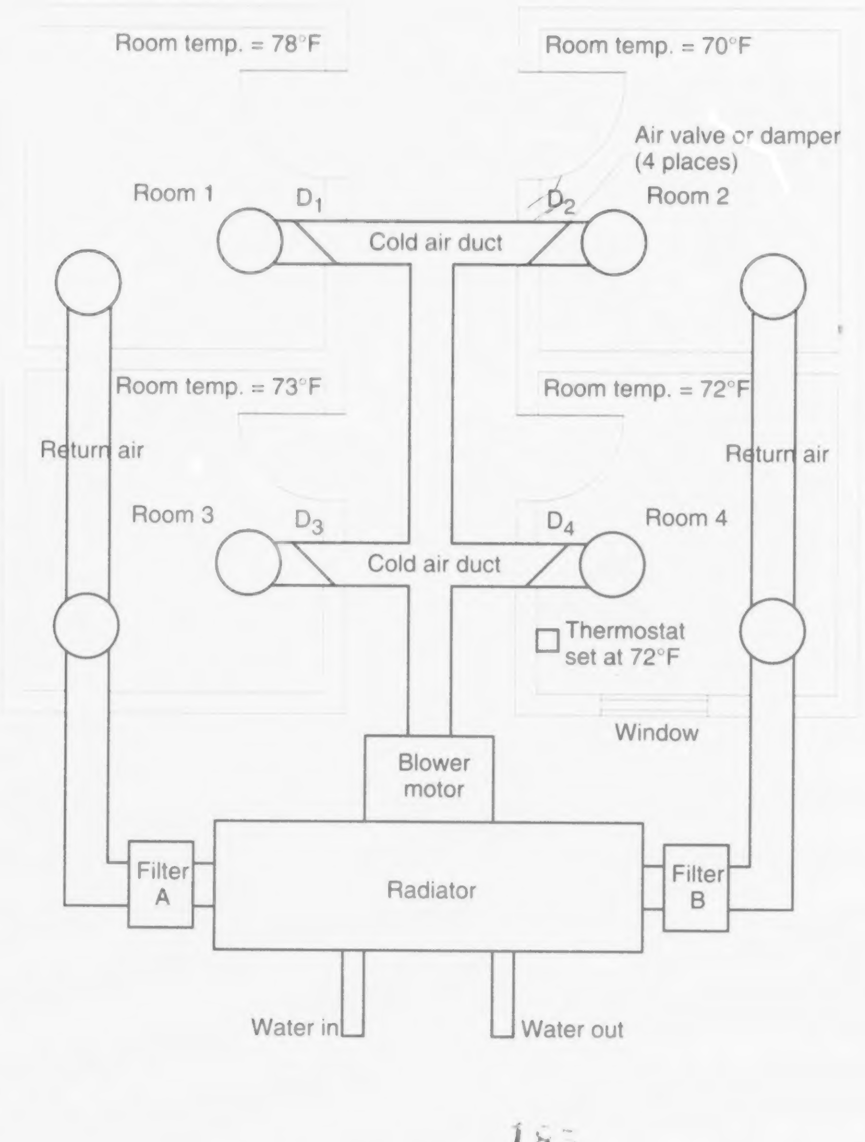
Thermometer
Manometer
Architect's schematic of a heating and cooling (HVAC) system
Pneumatic training materials, which includes hoses, T-connectors, a flow rate valve, and gauges

Procedure

1. Discuss the purpose of electrical thermostats in residential and commercial buildings. Ask learners to discuss the implications of a malfunctioning thermostat. Show learners what a thermostat looks like, if possible.
2. Allow learners to work in pairs or small groups to examine and read gauges to determine airflow rate.
3. Have learners work in pairs to review HVAC schematics. Instruct them to trace airflow of a cooling system by reading the schematic.
4. Have learners use a pneumatic training materials to construct an airflow system with 4 outputs. Then have them attach airflow valves to control the air output to the 4 lines. Then, to trace the path of air flow, have learners attach the airflow gauges to the 4 lines and read it.
5. Facilitate a discussion to summarize what has been learned.

Problem

In the springtime, four offices that are controlled by the same air-conditioning system are at different temperatures (as indicated on the following diagram). Some rooms have windows, and some do not. One thermostat controls all four rooms. As the diagram shows, each room has ductwork going to it, which ends in an air diffuser in the ceiling of that room. There is a circuit breaker to prevent electrical overload on the system. Your job is to equalize the temperature in the four rooms.


Room temp. = 78°F
Room temp. = 70°F
Air valve or damper (4 places)
Room 1
D_1
D_2
Room 2
Cold air duct
Room temp. = 73°F
Room temp. = 72°F
Return air
Return air
Room 3
D_3
D_4
Room 4
Cold air duct
Thermostat set at 72°F
Window
Blower motor
Filter A
Radiator
Filter B
Water in
Water out

Identify the Problem

1. What is the problem?
   A. The water going into the radiator is too hot.
   B. The temperature is different in each of the four rooms.
   C. There are not enough windows.
   D. The air ducts are the wrong size.
   E. There are too many cold air ducts.

2. The problem with the system could be that
   A. The water level is too low in the system.
   B. The circuit breaker has tripped.
   C. The blower system is not working correctly.
   D. The sun coming in the window is creating the malfunction.
   E. The thermostat is not operating.

Define the Problem

3. To identify the malfunction, first check
   A. The water pressure.
   B. The thermostat setting.
   C. The bearing on the blower motor.
   D. To see whether air is coming out of the diffusers in each room.
   E. The circuit breaker.

Explore Alternatives

4. To isolate the problem, you would first
   A. Measure airflow coming from the diffuser in each room.
   B. Measure the pressure drop across each filter.
   C. Check the water temperature before it enters and after it exits the radiator.
   D. Check the voltage going to the thermostat.
   E. Measure the temperature outside the building.

Act on a Plan

5. Below are various measurements taken in the system. Which would indicate an existing problem?
   - A. The pressure drop across Filter A is 2 psi (pounds per square inch); the pressure drop across Filter B is 2 psi.
   - B. Air leaving the radiator is 68° F; the temperature of the return-air duct is 76° F.
   - C. The air flow rate to each room is:

     Room 1—60 cfm
     Room 2—100 cfm
     Room 3—80 cfm
     Room 4—85 cfm
   - D. The motor speed is 1700 rpm.
   - E. The outside relative humidity is 90%.

Look at the Result

6. To equalize the airflow, you should change the airflow by
   - A. Opening D1 and closing D2 slightly.
   - B. Opening D3 and D4.
   - C. Closing D3 and D4.
   - D. Closing D1 and opening D2 slightly.
   - E. Opening D2, D3, and D4.

187

Answers

1. B
2. C
3. D
4. A
5. C
6. A

Instructor's Notes:

Thermodynamics Problem 5.2: **Transformer Box Fans**

Scientific Principles

Factors that affect the flow of air (e.g., heat, resistance) and actions of fuses and breakers

Background

Heat flows from hot areas to cooler areas and warm air rises. Fans only move air—they do not cool it. Furthermore, unless specified, fans draw air into the back and expel the air in front of the blades because air flows from high pressure to low pressure areas.

Fuses and breakers stop the flow of electrical current when the maximum temperature is exceeded.

Workers often encounter breakdown of a system when poor ventilation exists in or around equipment. Heat often accumulates, even in ventilated areas, as equipment achieves maximum levels of activity. It is important for workers to consider the interactions of different components, particularly in enclosed spaces. Furthermore, workers need to place equipment and/or system components within the constraints of the workplace environment in order to solve problems with those systems.

In this problem, several electrical components affect each other. The placement of a transformer box dictates that fans must be inside the box and near the center.

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Key Process Skills

(Refer to p. 24 for a description of each process skill.)

●	Observing
●	Communicating
●	Comparing
○	Ordering
○	Making models
●	Measuring
○	Recording
●	Interpreting data
●	Experimenting
●	Predicting
○	Hypothesizing
●	Inferring
○	Categorizing or classifying
●	Recognizing relationships
○	Controlling variables

Ohio Science Proficiency Outcomes

(Refer to Appendix D, pp. 335-337, for a description of each outcome.)

6th Grade	9th Grade	12th Grade
1 ●	1 ●	1 ○
2 ●	2 ●	3 ○
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6 ○	9 ○	12 ●
7 ○	10 ●	
8 ○	11 ○	
9 ●	12 ○	
10 ○	17 ○	
	19 ●	

Vocabulary

Component
Flow
Pressure
Current
Transformer
Vent
Breakers
Fuses
Celsius

Materials for Each Group of Learners

A fan
2 thermometers
Matches
A wet cloth
A rubber band or string to tie cloth
A Bunsen burner or other heat source
A beaker or other container that can be heated
Food coloring

Have pairs or small groups of learners conduct the activities described next. Have learners record their observations on Worksheet 5.2.

Learning Activity 1

Using 2 thermometers and a fan, blow air from the fan over 1 thermometer. Place the second thermometer near the fan where it does not catch the breeze. What happens to the temperature on each thermometer? Record your observations.
Answer: The temperatures do not change.

Learning Activity 2

Hold a smoking match below the fan so the smoke rises into the path of the breeze. Observe where the air flows. Record your observations.
Answer: The smoke moves away from the fan.

Learning Activity 3

Place a smoking match below the fan. Observe the airflow. Record your observations. Then place a smoking match behind the fan. Observe the airflow. Record your observations.
Answer: *The smoke is drawn into the fan.*

Learning Activity 4

Tie a wet cloth to the bulb of one of the thermometers and place the thermometer in the breeze of the fan. Then hold the other thermometer in the breeze. Record the temperature of each thermometer.
Answer: *The temperature of the thermometer wrapped in the wet cloth will drop; it will be lower than that of the unwrapped thermometer.*

Learning Activity 5

Fill a beaker with water and secure the beaker over a heat source, such as a Bunsen burner. When bubbles begin to rise, add a few drops of food coloring. Observe the convection currents in the beaker. Record your observations.
Answer: *If the heat source is at the bottom, the heated water will rise to the top of the container. This also holds true for the flow of air; warmer air rises.*

Synthesizing Activity

Facilitate a discussion that helps learners summarize what they learned. Ask them to describe how the same principles are important in the workplace.

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Worksheet 5.2

Name ____________________

1. Using 2 thermometers and a fan, blow air from the fan over 1 thermometer. Place the second thermometer near the fan but where it does not catch the breeze. What happens to the temperature of each thermometer? Record your observations below.

2. Hold a smoking match below the fan so the smoke rises into the path of the breeze. Observe where the air flows. Record your observations below.

3. Place a smoking match below the fan. Observe the airflow. Record your observations below.

   Place a smoking match behind the fan. Observe the airflow. Record your observations below.

4. Tie a wet cloth to the bulb of one of the thermometers and place the thermometer in the breeze of the fan. Then hold the other thermometer in the breeze. Record the temperature of each thermometer below.

5. Fill a beaker with water and secure the beaker over a heat source, such as a Bunsen burner. When bubbles begin to rise, add a few drops of food coloring. Observe the convection currents in the beaker. Record your observations below.

6. On the back of this sheet, summarize what you learned about heat and flow.

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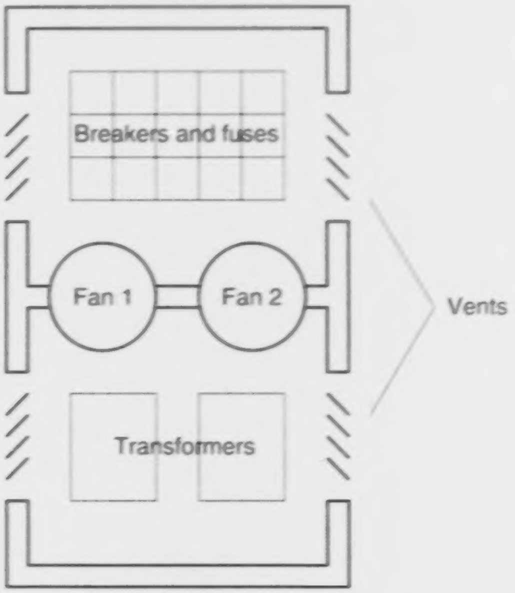
Problem

In a factory where you work, the plant temperature is maintained at 25 degrees Celsius. An electrical box that is mounted on the wall in the plant contains a bank of breakers and fuses in its top portion. Two transformers are located in the bottom area of the box. The breakers and fuses are temperature sensitive, rated up to 40 degrees Celsius. Each transformer can reach a temperature of 140 degrees Celsius without being damaged. The box's location, which is permanent, requires the fans to be inside the box and near the center. Your job is to install fans inside the box to maintain a safe operating temperature for the components.



Electrical box

Identify the Problem

1. What is your assignment?
   - A. To determine the correct position of the fans to keep components from overheating.
   - B. To determine where the electrical box should be placed in the plant
   - C. To determine what 140 degrees Celsius is in Fahrenheit
   - D. To determine whether the box size is correct for the plant
   - E. To determine whether the vents are arranged correctly

Define the Problem

2. What is the MOST important factor to consider in order to solve this problem?
   A. The size of the breakers and fuses
   B. The size of the fans
   C. The optimal airflow from the fans located in the center of the box
   D. The size of the vents
   E. Whether the metal of the electrical box is expanding or contracting from the heat

Explore the Alternatives

3. What is the BEST alternative for keeping the components from overheating?
   A. Arrange the angle of the vents.
   B. Open the doors in the plant.
   C. Turn one transformer off.
   D. Arrange the fans in the center of the box to circulate air from the top part of the electrical box to the bottom part.
   E. Increase the fuse size.

Act on a Plan

4. How should the fans be arranged for optimum airflow?
   A. The fans should be eliminated because they are producing heat.
   B. The fans should be facing each other and placed at either end of the electrical box.
   C. The fans should be positioned so they point directly out of each vent.
   D. Both fans should draw the warm air upward over the breakers and fuses to exit the top of the electrical box.
   E. Both fans should draw the cool air downward over the breakers and fuses to push the warmer air out of the bottom of the electrical box.

Look at the Result

5. Once you install the fans, are the components overheating?
   A. Yes
   B. No

Answers

1. A
2. C
3. D
4. E
5. B

Instructor's Notes:

Instructional Support Materials

Thermodynamics Problem 5.3: **Smog Hog**

Scientific Principles

Factors that affect the flow of air, including heat and resistance

Background

Because the manufacturing process often leaves byproducts that flow into the air, many manufacturing plants have air filtration systems. Workers need to know how to identify malfunctions in air filtration systems and to fix them.

Key Process Skills

(Refer to p. 24 for a description of each process skill.)

●	Observing
○	Communicating
●	Comparing
○	Ordering
○	Making models
●	Measuring
○	Recording
●	Interpreting data
●	Experimenting
●	Predicting
○	Hypothesizing
●	Inferring
○	Categorizing or classifying
●	Recognizing relationships
○	Controlling variables

Ohio Science Proficiency Outcomes

(Refer to Appendix D, pp. 335-337, for a description of each outcome.)

6th Grade	9th Grade	12th Grade
1 ●	1 ●	1 ○
2 ●	2 ●	3 ○
3 ●	3 ●	4 ●
4 ●	4 ●	5 ○
5 ●	8 ○	8 ○
6 ○	9 ○	12 ●
7 ○	10 ●	
8 ○	11 ○	
9 ●	12 ○	
10 ○	17 ○	
	19 ●	

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Vocabulary

Fumes
Exhaust
Forced-air furnace

Materials

Diagrams of industrial equipment

Learning Activity

Have learners practice reading diagrams of industrial equipment. Have them work in pairs to follow the flow of energy, air, and heat. Have learners describe how specific system parts affect others.

Problem

Your plant produces plastics. Exhaust fumes from the production process are collected by fume hoods and are treated in a device called a Smog Hog. The Smog Hog must be kept at a high temperature to operate properly. The heat in the system is input by a forced-air furnace.

It is your job to oversee the operation of the exhaust treatment process. You notice that the temperature of the Smog Hog (Temp. B) has dropped below the required operating temperature. You must correct the problem. Refer to the following diagram to answer questions about this problem.

Fume Collector System

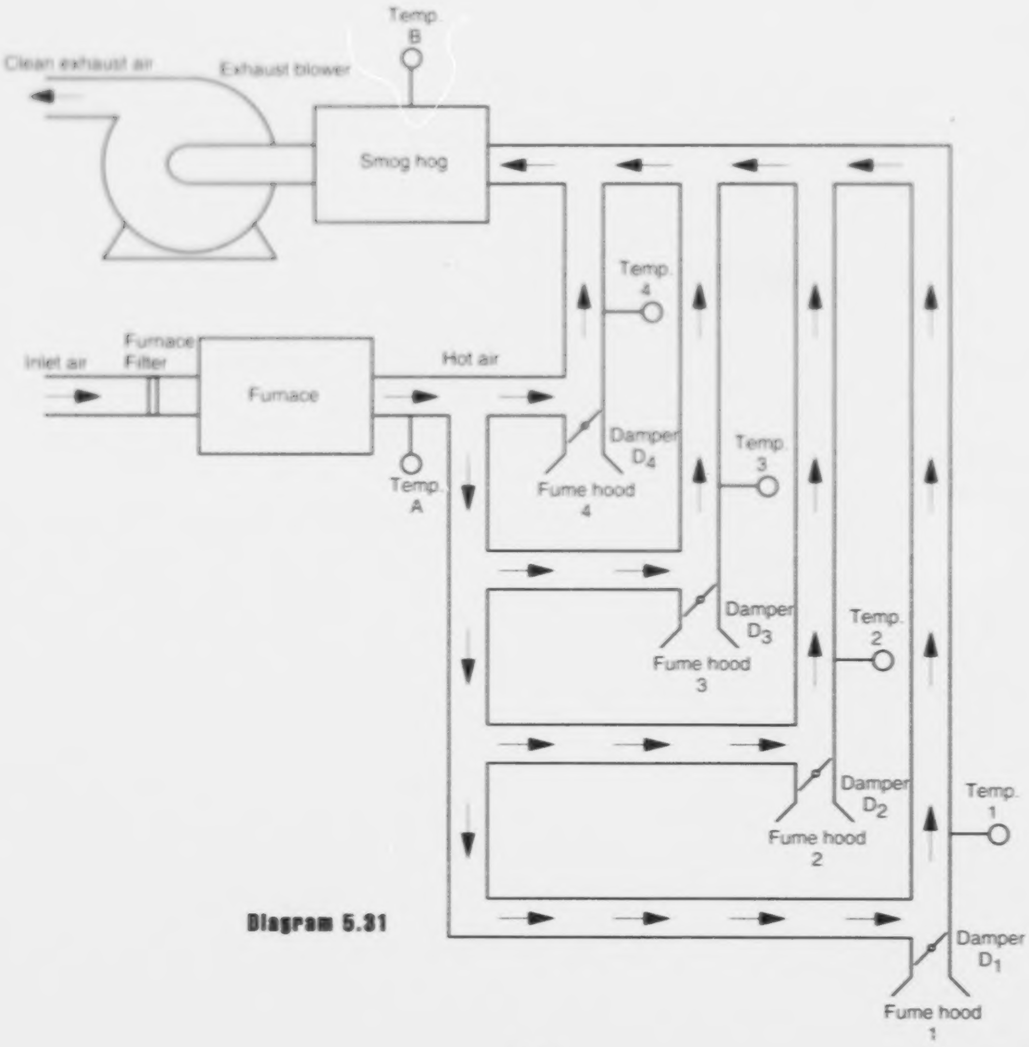
Temp. B
Clean exhaust air
Exhaust blower
Smog hog
Temp. 4
Inlet air
Furnace Filter
Furnace
Hot air
Damper D$_4$
Temp. A
Fume hood 4
Temp. 3
Damper D$_3$
Fume hood 3
Temp. 2
Damper D$_2$
Fume hood 2
Temp. 1
Damper D$_1$
Fume hood 1

Diagram 5.31

Identify the Problem

1. What have you been asked to do?
   - A. Recondition the air.
   - B. Lower the temperature in the room.
   - C. Raise the temperature of the Smog Hog.
   - D. Lower the temperature of the Smog Hog.
   - E. Call your supervisor.

Define the Problem

2. The problem is that
   - A. The exhaust blower is not functioning.
   - B. The operating temperature is too low.
   - C. No fumes are being collected.
   - D. Fume Hood 2 is not functioning.
   - E. The operating temperature is too high.

3. To locate the source of the problem, which of the following should you check FIRST?
   - A. The blower motor
   - B. The natural gas supply to the furnace
   - C. The temperature at Temp. A, 1, 2, 3, and 4
   - D. The furnace filter
   - E. The exhaust air

Explore Alternatives

4. What would be an indication of the source of the problem?
   - A. The furnace filter is clogged.
   - B. The blower motor is burned up.
   - C. The temperatures are as follows: Temp. 1-130°F; Temp. 2-135°F; Temp. 3-81°F; Temp. 4-129°F.
   - D. The exhaust blower motor's speed is 1750 rpm.
   - E. The inlet air is hot.

Act on a Plan

5. What would you do?
   - A. Open D1 slightly.
   - B. Remove the furnace filter.
   - C. Turn up the furnace temperature.
   - D. Close D3 slightly.
   - E. Open D2 slightly.

Look at the Result

6. After taking action, what would you expect to happen?
   - A. Temp. A and Temp. 2 will increase.
   - B. Temp. B and Temp. 3 will increase.
   - C. The blower motor's load will go down.
   - D. The airflow out of the exhaust will increase.
   - E. The furnace will turn off.

Answers

C
B
C
C
D
B

Instructor's Notes:

Fluid Dynamics Problem 5.4: **Mini-Oiler Air Line Lubricator**

Fluid dynamics

Scientific Principle

Principles of fluid dynamics, including flow, pneumatic pressure, and hydraulic pressure

Background

Fluid dynamics may involve any of the following: air, gas, water, or oil. Any of these can be used to create energy to lift, push, pull, or move things. A workplace application of this principle is described in the following example. (Problem 5.4 involves the same example.) One type of machine that is powered by compressed air is an air driver. In order for an air driver to last long and operate accurately, it must be lubricated properly. To assure that this happens, each drop of lubrication in an air driver is fed by a lubricator that is filled with a standard-grade pneumatic oil. Only one lubricator is needed for three drivers, if the drivers do not run at the same time. Each lubricator is fully adjustable so that drivers are provided with proper lubrication.

Key Process Skills

(Refer to p. 24 for a description of each process skill.)

●	Observing
●	Communicating
○	Comparing
○	Ordering
●	Making models
●	Measuring
●	Recording
●	Interpreting data
●	Experimenting
○	Predicting
○	Hypothesizing
○	Inferring
●	Categorizing or classifying
●	Recognizing relationships
○	Controlling variables

Ohio Science Proficiency Outcomes

(Refer to Appendix D, pp. 335-337, for a description of each outcome.)

6th Grade	9th Grade	12th Grade
1 ●	1 ●	1 ●
2 ●	2 ○	3 ●
3 ○	3 ●	4 ●
4 ●	4 ●	5 ●
5 ●	8 ○	8 ○
6 ●	9 ●	12 ○
7 ○	10 ○	
8 ○	11 ○	
9 ○	12 ○	
10 ○	17 ●	
	19 ●	

Vocabulary

Potential energy
Mechanical energy
Fluid energy
Psi (pounds per square inch)
Torque
Pneumatic
In lb (inch pound)
Shut-off valve
Moisture separator/evaporator
Quick disconnect
Compressed air
Torque analyzer
Hydraulic
Fluid
Regulator
Lubricator
Filter
Air driver

Learning Activity1

Discuss the meaning of fluid dynamics with learners. Stress that fluid dynamics may involve any of the following: air, gas, water, or oil, and that these can be used to create energy to lift, push, pull, or move things.

Learning Activity 2

Make a chart (similar to the one below) that helps learners distinguish mechanical energy from fluid energy. You may wish to begin with one or more of the examples below. Have learners add examples to the chart.

Mechanical Energy	Fluid Energy
cookie press	water moving a water wheel
caulking gun	furnace air moving a curtain
toothpaste tube or pump	oil in a hydraulic shock absorber

Learning Activity 3

Discuss how a helium tank is used to blow up balloons.

Learning Activity 4

Materials for Each Group of Learners

Paper (8 ½″ x 11″)
Straight pin
Straw or dowel (for pinwheel handle)
Balloon

Facilitate the activity below either by conducting a demonstration or having learners perform the following tasks.

1. Construct a pinwheel from paper (for the pinwheel), a straight pin (to hold the pin wheel to the handle), and a straw or dowel (for the handle).
2. Blow up a balloon and let the air out near the pinwheel.
3. Discuss how air (i.e., energy) can be stored to do work at a later time.

Learning Activity 5

Materials for Each Group of Learners

PVC pipe (cut into several different lengths (e.g., 6″, 10″, and 12″)
Rubber band
Tissue
Hand-operated bicycle pump

Using pieces of PVC pipe, construct a sample flow pattern for air or water. Then use a rubber band to attach a tissue to the end of the pipe. Blow air into the pipe using a hand-operated bicycle pump. (The tissue will move when air is blown into the pipe.) Use T's and shutoffs to redirect the flow of air. Discuss how this principle is used in everyday systems.

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Learning Activity 6

Materials for Each Group of Learners

An empty dishwashing soap bottle
Small amount of modeling clay

Demonstrate how powerful compressed air is by doing the following:

1. Take a nozzle off of an old dishwashing soap bottle and put a small lump of modeling clay into the neck to make it airtight. (You can assure airtightness by putting the bottle close to your ear and listening for any escaping air as you squeeze the bottle.)
2. Take the bottle outside and lay it on the ground. CAUTION: Don't point it toward anyone!
3. Have someone jump on the bottle and compress the air inside. The clay plug will shoot out at great speed—it is driven by compressed air.

Learning Activity 7

Facilitate a discussion about the flow of air, gas, water, and oil. Have learners brainstorm ways in which air, gas, water, and oil is used to move energy (which results in work being done). Use examples, such as the following, to show energy movement.

Air: Aqua-Lung (compressed air and gas)
Vacuum cleaner (reversed airflow)
Windmill (wind-driven water pump)
Forced-air furnace heating system
Pinwheel
Helicopter blades
Air line at a gas station (compressed air)

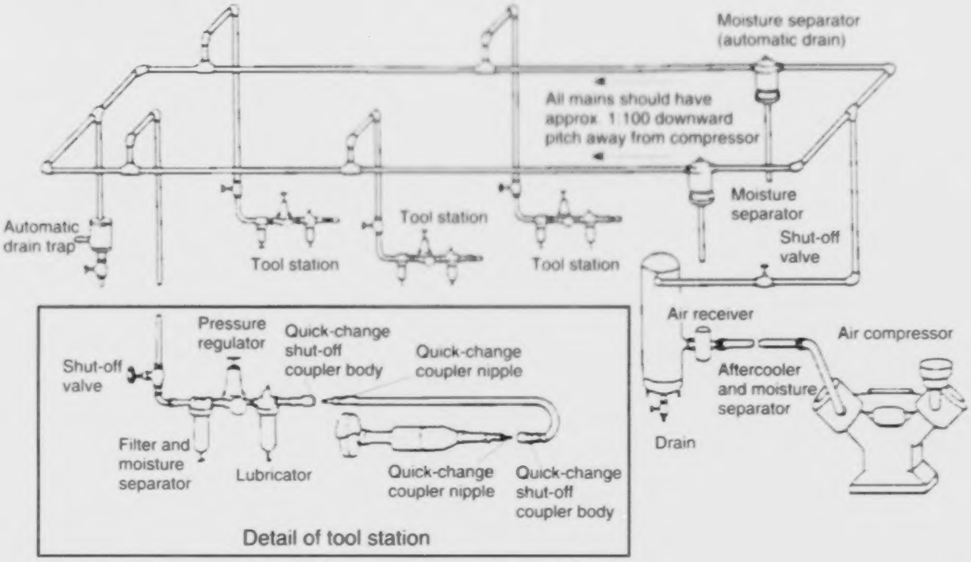
Water: Toilet tank
Fire hose (pressurized water)
Mill wheel (flow of water moving a grinding wheel)
Waterline in a home (pressurized to allow water to run uphill)
Water tower (holds a large quantity of water as stored energy; allows water to flow as needed)

Oil: Hydraulic jack
Car shock absorbers
Hatchback closing on a car
Dump truck
Garbage truck
Log splitter

Problem

The diagram below illustrates the Mini-Oiler, including the air drivers and lubricators at its tool stations.

Mini-Oiler Air Line Lubricator


Moisture separator (automatic drain)
All mains should have approx. 1:100 downward pitch away from compressor
Moisture separator
Shut-off valve
Automatic drain trap
Tool station
Tool station
Tool station
Air receiver
Air compressor
Aftercooler and moisture separator
Drain
Shut-off valve
Pressure regulator
Quick-change shut-off coupler body
Quick-change coupler nipple
Filter and moisture separator
Lubricator
Quick-change coupler nipple
Quick-change shut-off coupler body

Detail of tool station

Mini-Oiler Layout

The above layout shows a filter/regulator/lubricator at every tool station of an ATM production line. The line is powered by compressed air. Various tools needed in the manufacturing process are attached to the coupler nipples of the tool stations.

In order for an air-driven tools to last long and operate accurately, they must be lubricated properly. To assure that this happens, the air driver at each tool station is fed by a lubricator that is filled with a standard-grade pneumatic oil. Only one lubricator is needed for three air-driven tools, if the tools are not used at the same time. Each lubricator is fully adjustable so that drivers are provided with proper lubrication.

Mini-Oiler Filling Instructions

The following steps must be followed to fill the oilers and to keep adequate oil supplied to the air drivers. NOTE: Operators should never let Mini-Oilers get below the empty mark.

1. The air lines going into the oiler must be disconnected to perform this activity.
2. Inspect the clear base for water, foam, bubbles, etc. If any of these substances are present, contact the maintenance department for repair.
3. Unscrew the filler screw on the top of the Mini-Oiler, under the red cap. Add oil to the full mark. Place the filler screw back on and tighten it.

You are a trained associate at a plant that produces automated teller machines (ATMs). You have been certified in the use of air drivers, which provide power to the manufacturing line's air-driven tools. You are responsible for using the appropriate torque analyzer to check the torque of your air driver each month or when torque values are suspect. You must take the average of five readings. You are also responsible for recording the results of your inspections. The torque specification should be from 14 to 18 in lb (inch pounds). This month's readings on your air driver are as follows: 13.45 lb, 12.30 lb, 13.60 lb, 14.25 lb, and 12.65 lb. In addition, you have noticed excessive heat buildup on the air driver during the past month. It is your responsibility to determine what the problem is and to fix it.

Identify the Problem

1. Your assignment is to
   A. Replace your air driver.
   B. Determine the reason for the heat and low torque readings on the air driver.
   C. Adjust the torque on your air driver.
   D. Move to another station.
   E. Quit for the day.

Define the Problem

2. What do you need to consider when troubleshooting this problem?
   A. How many workstations are on the same air-supply line
   B. Whether the torque readings are in the appropriate range
   C. The temperature outside
   D. The grade of oil that is being used
   E. The humidity outside

Explore Alternatives

3. To determine possible explanations for the malfunction, you should
   A. Check for pipe leaks.
   B. Check the compressor.
   C. Check the oil lubricator.
   D. Ignore it and assume that the torque analyzer is bad.
   E. Obtain a fan to cool the workstation.

4. Of the following, which would be the most likely cause of the problem?
   A. The relative humidity for the day is extremely high.
   B. The lubricator lacks oil.
   C. There are too many work stations off of the main air supply.
   D. There is a blockage in the system piping.
   E. You are applying too much pressure to the air driver.

Act on the Plan

5. What action will you now take?
   - A. Add a fan to cool the air driver.
   - B. Shut down your station and take the driver to another work station.
   - C. Add oil to the lubricator.
   - D. Adjust the psi on the compressor.
   - E. Use a hand driver to allow your driver to cool down.

Look at the Result

6. After half an hour of using the tool, you
   - A. Do nothing more and assume that the torque rating is close enough.
   - B. Do nothing since the tool feels cooler.
   - C. Recheck using the torque analyzer to assure that the reading falls between 14 and 18 lb.
   - D. Visually inspect the hardware to make sure that it is working properly.
   - E. Decide that you need another fan at your workstation.

Answers

1. B
2. B
3. C
4. B
5. C
6. C

The authors of this problem thought that it would be helpful to provide instructors with explanations about why some choices for questions in this fluid dynamics problem are incorrect.

1. Correct answer: B
   - A. You have been certified in the use and maintenance of the air driver.
   - C. You have not been certified in adjusting torque.
   - D. This would cause disruption on the line and interfere with another's work.
   - E. This is an inappropriate response.
2. Correct answer: B
   - A. You are not qualified to determine this.
   - C. Outside temperature will not affect your driver.
   - D. All the torque drivers use the same grade of oil.
   - E. The humidity is not a factor.
3. Correct answer: C
   - A. If there was a leak in the hose other drivers would also be affected.
   - B. You are not empowered to do anything with the compressor.
   - D. You cannot ignore the problem.
   - E. Cooling the work station will not affect the driver.
4. Correct answer: B
   - A. The relative humidity will not affect the torque on your air driver.
   - C. The number of work stations off the main supply is appropriate.
   - D. The hoses are made of fixed piping.
   - E. A manual tool, like a screw driver, would not give you appropriate torque in a consistent manner.

5. Correct answer: C
   - A. Adding a fan will not affect the driver.
   - B. This would disrupt others and close another tool station down.
   - D. You are not empowered to adjust the in lb.
   - E. You will be unable to achieve the correct torque with a hand driver.

6. Correct answer: C
   - A. This would be an inappropriate action.
   - B. This would be an inappropriate action.
   - D. A visual inspection will not allow you to determine if the problem has been corrected.
   - E. Another fan will not solve the problem.

Instructor's Notes:

Instructional Support Materials

Wall switch
110 V Outlet
Electricity

Electricity Problem 5.5: **Boat Trailer Lights**

Scientific Principle

Basic electrical principles that are involved in diagnosing the electron flow in multiple-branch DC circuits, including Ohm's law. (Refer to Appendix C for additional information.)

Background

Diagnosing faulty electrical circuits gives excellent practice at solving electrical problems. In this section's learning activities, learners identify and repair defective components of circuits.

Key Process Skills

(Refer to p. 24 for a description of each process skill.)

●	Observing
●	Communicating
○	Comparing
○	Ordering
○	Making models
●	Measuring
○	Recording
●	Interpreting data
●	Experimenting
○	Predicting
○	Hypothesizing
○	Inferring
○	Categorizing or classifying
●	Recognizing relationships
○	Controlling variables

Ohio Science Proficiency Outcomes

(Refer to Appendix D, pp. 335-337, for a description of each outcome.)

6th Grade	9th Grade	12th Grade
1 ●	1 ●	1 ○
2 ●	2 ○	3 ○
3 ○	3 ●	4 ●
4 ●	4 ●	5 ○
5 ●	8 ○	8 ●
6 ○	9 ○	12 ●
7 ○	10 ●	
8 ○	11 ○	
9 ●	12 ○	
10 ○	17 ●	
	19 ●	

Vocabulary

Circuit
Continuity
Voltage
Volt
Amp
Ohm
Ohmmeter

Materials

Ladder logic diagrams and circuit diagrams (including correct ladder circuits and bugged circuits)
Actual circuit components (including operational components and defective components)
Ohmmeters

NOTE: The activities suggested in this section require more specialized equipment and resources than are readily available to many instructors. You are encouraged to refer to the books described in the Resource section, pp. 307-319. In addition, it would be helpful to speak with an electricity or electronics teacher at your local vocational school about strategies and materials for teaching principles related to electricity.

Have learners complete the following activities that follow.

Learning Activity 1

Demonstrate how ohmmeters are used to measure voltage, ohms, amps, and continuity. Have learners practice making measurements.

To learn and practice measuring voltage, complete the two worksheets in this section.

Learning Activity 2

Have learners work individually or in pairs to debug ladder and circuit diagrams by identifying and repairing defective components.

Learning Activity 3

Work individually or in pairs to build operational circuits from given diagrams.

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Electricity Problem 5.5 **Worksheet 5.51**

Using a Voltmeter

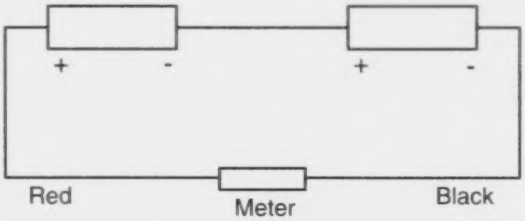
Name ______________________________

1. Turn on your voltmeter and set it to the 20-volt DC scale.
2. Touch the ends of the black and red meter leads to the battery terminals.

   What does the meter read? ______________________
3. Reverse the meter leads.

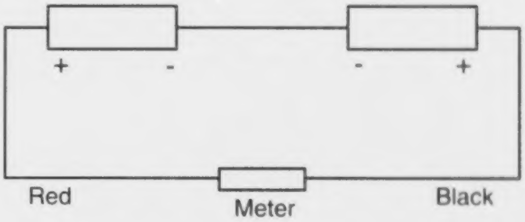
   What does the meter indicate? ______________________
4. Use the jumper lead to connect two batteries in series.

   What does the meter read? ______________________



5. Reverse the polarity of one of the batteries in question 4.

   What does the meter read? ______________________



6. Hook a lightbulb to one of the batteries.

What is the voltage across the lightbulb? ______________________________

7. Hook two lightbulbs in series across a battery.

What is the voltage reading across each lightbulb? ______________________________

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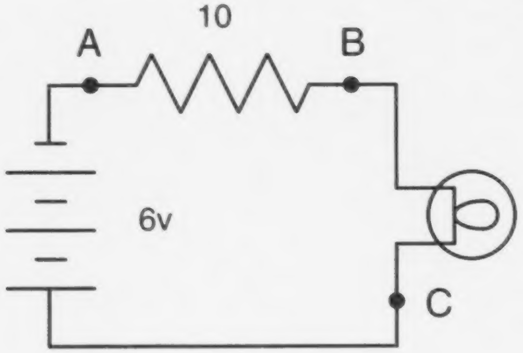
Electricity Problem 5.5

Calculating Voltage

Name ____



1. Set up the circuit as shown above.

2. Measure the voltage drop across the 10Ω resistor.

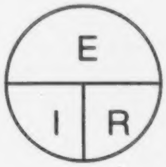
____

3. Using Ohm's law, calculate the current through the 10Ω resistor.

____

4. Measure the voltage drop across the lightbulb.

____



5. Using Ohm's law and the information from questions 3 and 4, find the resistance of the lightbulb while it is hot.

____

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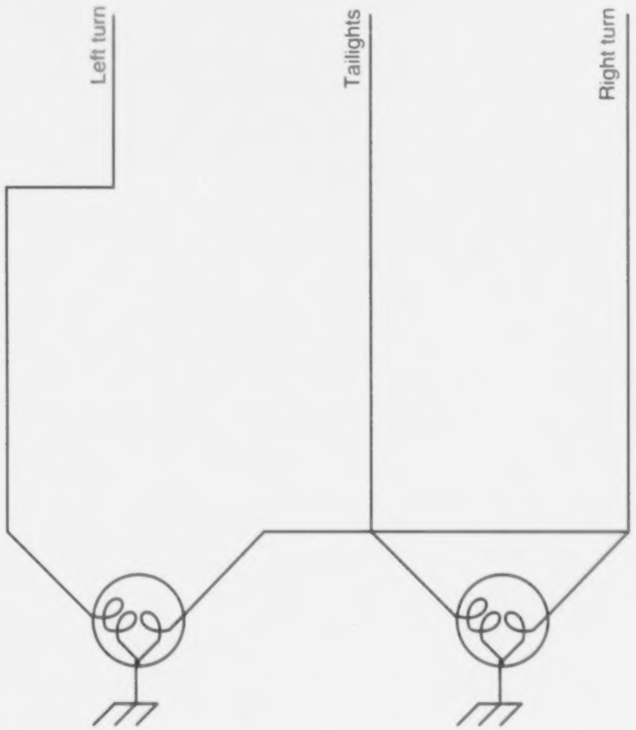
Problem

After a long, fun-filled day of waterskiing, you transfer your boat from the water to a trailer and prepare it for the long drive home after dark. When you check the taillights on the trailer, you notice that they both work properly. With the taillights still turned on, you notice that the left trailer turn signal works properly but that the right turn signal causes both trailer taillights to flash at only half brightness. All of the car taillights and turn signals operate properly. What must be done to fix the lights?

You may wish to refer to the following diagram of the lighting on a trailer to answer the questions related to this problem.

Trailer Lights



Identify the Problem

1. What is the problem?
   - A. The trailer's right turn signal is working improperly.
   - B. The trailer's left turn signal is working improperly.
   - C. The car's right turn signal works improperly.
   - D. The car's left turn signal works improperly.
   - E. The car's taillights work improperly.

Define the Problem

2. Where is the most probable location of the problem?
   A. The car wiring
   B. The plug going from the car to the trailer
   C. The right taillight battery-positive circuit on the trailer
   D. The right turn signal battery-positive circuit on the trailer
   E. The grounding circuit for the right trailer light and turn signal

3. Which statement BEST describes the defective circuit?
   A. It is missing a battery positive to the taillight filament.
   B. It is missing a battery positive to the left turn signal filament.
   C. It lacks of a proper ground between the trailer chassis and the car.
   D. It lacks of a proper ground between the lightbulb and the trailer chassis.
   E. There is a poor ground between the trailer and the car.

Explore Alternatives

4. What is the most likely cause of the problem?
   A. A blown fuse
   B. A bad lightbulb
   C. A broken battery-positive wire
   D. A bad ground
   E. A loose bulb

Act on a Plan

5. What voltage and resistance measurements would be most helpful?
   A. The voltage of the battery positive for the trailer taillight
   B. The voltage of the battery positive for the trailer turn signal
   C. The resistance of the taillight filament
   D. The resistance of the turn signal filament
   E. The resistance to the chassis of the lightbulb base

Look at the Result

6. How could a jumper wire that you found in your trunk be used to fix the light and get you home?
   A. To jump from the trailer ground to the car ground
   B. To jump from the car taillight's battery positive to the trailer taillight's battery positive
   C. To jump from the lightbulb's base to the trailer's chassis
   D. To jump from the car turn signal's battery positive to the trailer's turn signal battery positive
   E. To jump from the lightbulb's base to the car turn signal's battery positive

Answers

1. A
2. E
3. D
4. D
5. E
6. C

Instructor's Notes:

Instructional Support Materials

Wall switch
Electricity
110 V Outlet

Electricity Problem 5.6: Machine Indicator Lights

Scientific Principle

Basic electrical principles, including Ohm's law (Refer to Appendix C for additional information.)

Background

In this section, learners will have several opportunities to practice problem solving with electrical systems.

Key Process Skills

(Refer to p. 24 for a description of each process skill.)

●	Observing
●	Communicating
●	Comparing
◐	Ordering
●	Making models
◐	Measuring
●	Recording
◐	Interpreting data
●	Experimenting
●	Predicting
◐	Hypothesizing
◐	Inferring
◐	Categorizing or classifying
●	Recognizing relationships
●	Controlling variables

Ohio Science Proficiency Outcomes

(Refer to Appendix D, pp. 335-337, for a description of each outcome.)

6th Grade	9th Grade	12th Grade
1 ●	1 ●	1 ●
2 ●	2 ◐	3 ◐
3 ◐	3 ●	4 ●
4 ●	4 ●	5 ◐
5 ●	8 ◐	8 ●
6 ◐	9 ◐	12 ◐
7 ◐	10 ●	
8 ●	11 ●	
9 ●	12 ●	
10 ●	17 ●	
	19 ●	

Instructor's Notes:

Vocabulary

Indicator
Components
Schematic
Fuse
Power supply
Resistance
Circuit
Resistor
Ampere
Voltage

Materials

Battery bulbs
Coated copper wires
Power source (AC or DC—depending on what is available)
Fuses (some operational, some burned out)
Resistors (anything that slows down electrical load by using electricity)

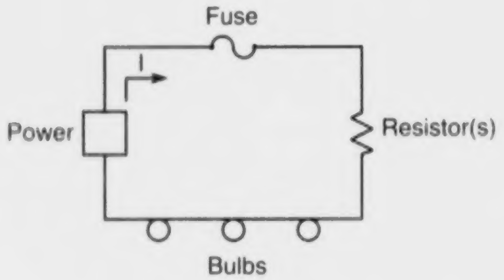
NOTE: The activities suggested in this section require more specialized equipment and resources than are readily available to many instructors. You are encouraged to refer to the books described in the Resource section, pp. 307-325 and to speak with an electricity or electronics teacher at your local vocational school.

Learning Activity

Instruct learners to do the activities described on the following worksheet. (An instructor's answer sheet is included.) After the learners have completed the activities, facilitate a discussion during which learners summarize what they learned.

Electricity Problem 5.6 **Worksheet**

1. Assemble a series circuit according to the diagram that follows.



2. Predict what will happen when one bulb is removed from the socket. Then remove one bulb from the socket. Observe what happens and record your findings.

Prediction: ______________________________

Observation: ______________________________

3. Predict what will happen when one bulb is removed from the circuit. Then remove one bulb from the circuit, but keep the circuit complete. Observe what happens and record your findings.

Prediction: ______________________________

Observation: ______________________________

4. Predict what will happen when the fuse is removed and the circuit is reconnected. Then remove the fuse and reconnect the circuit. Observe what happens and record your findings.

Prediction: ______________________________

Observation: ______________________________

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5. Predict what will happen when the fuse is replaced with a burned-out fuse. Then replace the fuse with a burned-out fuse. Observe what happens and record your findings.

Prediction: ______________________________

Observation: ______________________________

6. Predict what will happen when the resistor is removed and the circuit is reconnected. Then remove the resistor and reconnect the circuit. Observe what happens and record your findings.

Prediction: ______________________________

Observation: ______________________________

7. Predict what will happen when the resistor is removed. Replace the operational resistor with a burned out resistor. Observe what happens and record your findings.

Prediction: ______________________________

Observation: ______________________________

8. Optional Activity: Using the meter scale, determine current and voltage readings for the entire circuit and for affected sections of the circuit. Record your findings.

____

____

____

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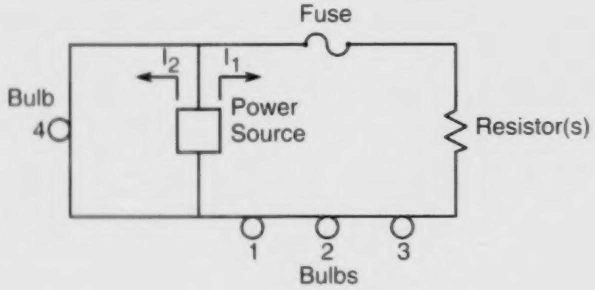
9. Build a circuit according to the following diagram. (It is similar to the diagram used earlier on this worksheet. The circuit is the same but a parallel branch with one bulb has been added.)



10. Predict what will happen if Bulb 4 is removed from the socket. Remove Bulb 4. Record your observations.

Prediction: ____________________

Observation: ____________________

11. Predict what will happen if Bulb 1 is removed from the socket. Remove Bulb 1. Record your observations.

Prediction: ____________________

Observation: ____________________

12. In the space below, summarize what you learned about electrical systems from doing the activities included in this exercise.

____

____

____

____

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Electricity Problem 5.6 — Instructor Answer Worksheet

1. Assemble a series circuit according to the diagram.
What happens when one bulb is removed from the socket?
Answer: *All of the bulbs go out. There is only one path for current. The current is the same at all points in the circuit.*

2. What happens when one bulb is removed from the circuit?
Answer: *The two bulbs burn brighter. The circuit voltage divides across resistors in a series. The sum of voltages equals the total voltage.*

4. What happens when the fuse is removed and the circuit is reconnected?
Answer: *There is no change. The lights burn.*

5. What happens when the fuse is replaced with a burned out fuse?
Answer: *No current flows and nothing lights.*

6. What happens when the resistor is removed and the circuit is reconnected?
Answer: *Lights may burn brighter depending on how large the resistors are.*

7. What happens when the resistor is removed and replaced with a burned-out resistor?
Answer: *No current flows and nothing lights.*

8. Use the meter scale, determine current and voltage readings for the entire circuit and for the affected sections of the circuit.
Answers will vary, depending on the load.

9. Assemble a series circuit according to the diagram.

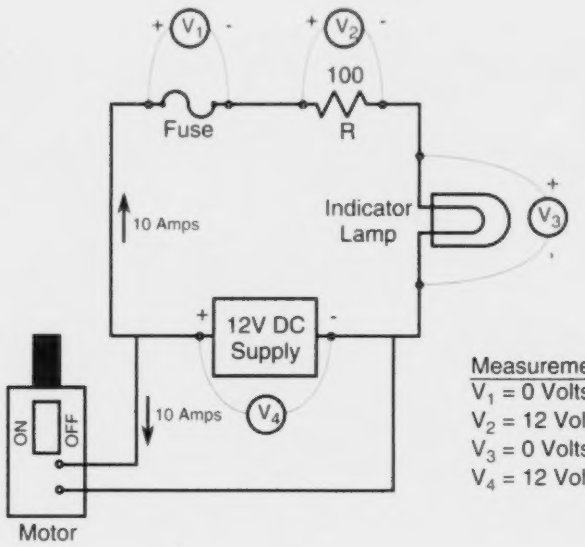
10. What happens when Bulb 4 is removed from the socket?
Answer: *Bulbs 1, 2, and 3 burn.*

11. What happens when Bulb 1 is removed from the socket?
Answer: *Bulbs 2 and 3 go out. Bulb 4 burns.*

12. Summary
Answers will vary. Use the information provided in the Background section of this problem as a guideline for judging written answers and for content of discussion.

Problem

You are the maintenance person at a plant. Part of your responsibility is to check the indicator lights on all machinery. For safety reasons, indicator lights must be lit while the machines are running. As you walk through the plant, you notice that a machine is running, but its indicator light is out. You take voltage measurements across the various components V1, V2, V3, and V4, as indicated on the following schematic. It is your responsibility to determine the problem and correct it.



Measurements Taken
V_1 = 0 Volts
V_2 = 12 Volts
V_3 = 0 Volts
V_4 = 12 Volts

Identify the Problem

1. What is your assignment?
   - A. To determine if the power supply is good
   - B. To determine the size of the lamp
   - C. To determine the size of the motor
   - D. To determine the reason why the indicator light is out although the machine is on
   - E. To determine the length of the wire from the motor to the lamp

Define the Problem

2. What do you need to consider to solve this problem?
   - A. The wattage of the lamp
   - B. Which circuit is involved with the lamp being out
   - C. The size of the power supply
   - D. The size of the fuse
   - E. The gauge of the wire

Explore Alternatives

3. Does your voltage reading correspond with what should be happening if there is current flowing through each device?
   - A. Zero voltage across the fuse indicates the fuse is the problem.
   - B. 12 volts across the resistor and no current indicates the resistor is blown.
   - C. Zero volts across the lamp indicates the light is bad.
   - D. The fuse is bad because there is no current.
   - E. The DC Supply is not functioning.

Act on a Plan

4. What is the appropriate action to correct the problem?
   - A. Replace the resistor.
   - B. Replace the lamp.
   - C. Replace the fuse.
   - D. Buy a new motor.
   - E. Buy a new power supply.

Look at the effect

5. Does the indicator light work?
   - A. Yes
   - B. No

Answers

1. D
2. B
3. B
4. A
5. A

Instructor's Notes:

Mechanics Problem 5.7: Lawn Mower Start-up

Scientific Principle

This section focuses on identifying the logical cause for the mechanical failure of an engine—given a specific set of circumstances. It also helps learners identify the best course of action to fix a mechanical problem and to examine the effectiveness of their work.

Background

Learners often have difficulty seeing the relationship of one component to an entire mechanical system. This problem leads learners to understand the effect that valves have on an engine system by questions that require the use of relational logic.

Key Process Skills

(Refer to p. 24 for a description of each process skill.)

●	Observing
●	Communicating
●	Comparing
○	Ordering
○	Making models
●	Measuring
○	Recording
●	Interpreting data
●	Experimenting
●	Predicting
○	Hypothesizing
●	Inferring
○	Categorizing or classifying
●	Recognizing relationships
○	Controlling variables

Ohio Science Proficiency Outcomes

(Refer to Appendix D, pp. 335-337, for a description of each outcome.)

6th Grade	9th Grade	12th Grade
1 ●	1 ●	1 ○
2 ●	2 ●	3 ●
3 ●	3 ●	4 ●
4 ○	4 ●	5 ○
5 ●	8 ●	8 ○
6 ●	9 ●	12 ○
7 ○	10 ○	
8 ○	11 ○	
9 ●	12 ○	
10 ○	17 ○	
	19 ●	

Vocabulary

Valve
Engine compression
Resistance

Materials

Small gasoline-powered engine (e.g., chain saw, outboard motor)
Hand tools required to disassemble engine
Compression tester
Small engine diagram (which is included in mechanics Problem 5.7)
A cross-section of a small gasoline engine (if available)

NOTE: These materials may be available from a vocational program at your school or a shop in your business.

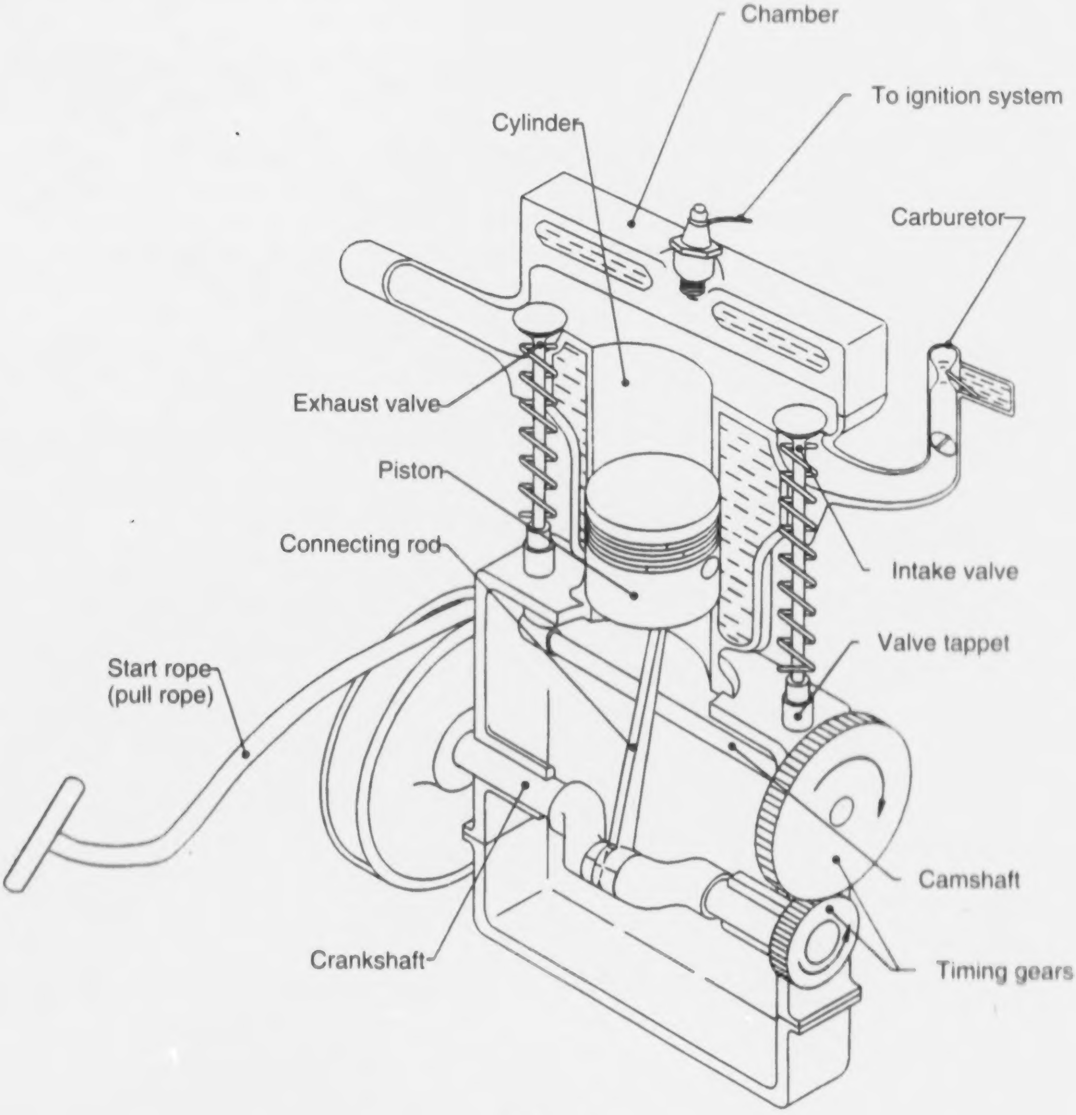
Learning Activity

To help learners understand how engines work and how to solve engine-related problems, guide them through the following activities.

1. Using a disassembled engine or the diagram on the following page, explain the way in which *valves* impact how an engine runs, with a special emphasis on *engine compression*.
2. Have learners pull the start cord on a properly working engine. Have them note how much resistance there is to start the engine.
3. Remove the intake valve to simulate a valve that is stuck open.
4. Have learners pull the start cord again. Have them note how little resistance there is on the start cord. Ask them to predict whether or not the engine will run.
5. Have learners perform a compression test on the engine.
6. Ask learners to brainstorm possible reasons for the lack of compression.
7. Instruct learners to make necessary changes in the engine to remedy the lack of compression (e.g., replace valve).
8. Facilitate a discussion during which learners summarize what they learned. Ask them to think about examples of workplace problems that may involve the lack of engine compression.

Problem

You work at a local lawn-mower repair shop. One day, a customer brings in her lawn mower and explains that it will not start. She has already checked the fluid levels and determined that the spark plug is in working order. When she pulls the start cord, however, it seems to pull too easily, as though there is very little resistance. What can be done to restore the lawn mower to working order? Use the following diagram as needed.


Chamber
To ignition system
Cylinder
Carburetor
Exhaust valve
Piston
Connecting rod
Intake valve
Valve tappet
Start rope
(pull rope)
Camshaft
Crankshaft
Timing gears

Identify the Problem

1. What is the problem?
   - A. It is too difficult for the customer to pull the cord properly.
   - B. The lawn mower will not start properly.
   - C. The customer wants to be able to start her lawn mower by using a key instead of a start cord.
   - D. The lawn mower brand is not the brand the customer is used to operating.
   - E. The length of the start cord must be at least 15 feet.

2. Why doesn't the lawn mower start?
   - A. It has no fuel to power the engine.
   - B. It has no oil to lubricate the engine.
   - C. There is little resistance on the start cord.
   - D. The spark plug needs to be replaced.
   - E. The customer lacks the strength to make the engine turn over fast enough when she pulls the start cord.

Define the Problem

3. Why doesn't the start cord have enough resistance?
   - A. The start cord is broken in two.
   - B. The engine has too much oil.
   - C. The start cord has become frayed from wear and tear.
   - D. There is no engine compression.
   - E. There is no engine lubricant.

Explore Alternatives

4. If the engine's valves were stuck open, the effect would be as follows:
   - A. The engine would run, but not as efficiently.
   - B. The piston would not move up and down.
   - C. The start cord would pull with little resistance; the crankshaft would move the piston up and down, but there would be no compression; and the engine would not start.
   - D. The start cord would pull with great resistance; the crankshaft would move the piston up and down; and the engine would have compression and start.
   - E. The open valves would result in higher engine performance.

Act on a Plan

5. Assuming there is nothing wrong with the starting-cord mechanism, what would be your first step in determining why the start cord has little resistance?
    - A. Check the tightness of all engine bolts.
    - B. Dismantle the lawn mower engine to explore possible problems.
    - C. Do an engine compression test.
    - D. Make sure the lawn mower has blade attached.
    - E. Check to be sure the throttle is in the "run" position.

6. Which of the following causes would be the MOST accurate reason the engine has no compression?
    - A. The intake and exhaust valves are closed, while the piston is traveling upward during the compression stroke.
    - B. The intake valve is open and the exhaust valve is closed, while piston is traveling upward during the compression stroke.
    - C. There is corrosion on the outside of the engine.
    - D. The intake valve is open and the exhaust valve is closed, while the piston is traveling downward during the intake stroke.
    - E. The engine appears old and outdated.

Look at the Result

7. After repairing stuck valves and reassembling the engine, what should you do next?
    - A. Immediately call the customer and tell her the lawn mower is fixed.
    - B. Ask your boss for a pay raise for a job well done.
    - C. Using a tension indicator, test the start cord to make sure it has proper resistance.
    - D. Test mow a patch of lawn at least 150' x 150'.
    - E. Test the engine compression, then start the mower to make sure it works.

Mechanics Problem 5.7

Answers

Answers

1. B
2. C
3. D
4. C
5. C
6. B
7. E

Instructor's Notes:

Mechanics Problem 5.8: Truck Loading

Scientific Principle

The primary principles involved in this problem are spatial relations and patterns; weights and measures; and balance.

Background

Learners must be able to find patterns, compare patterns, and grasp changing orientation in space. By having learners visualize the final product from a flat, folded box, the instructor will help them develop the skills necessary to function in today's workplace.

Spatial Orientation (adapted from *Spatial Encounters*, U.S. Department of Education) Spatial visualization involves the ability to manipulate and rotate mentally two-dimensional and three-dimensional objects. Spatial orientation involves the ability to perceive the elements in a pattern, to compare patterns, to grasp changing orientation in space, and to determine the position of one's body in space. The spatial skills of visualization and orientation are highly correlated with success in a number of technical and professional occupations that have traditionally been considered male domains. Spatial orientation is necessary for tasks that require a sense of direction, such as reading a map.

Key Process Skills

(Refer to p. 24 for a description of each process skill.)

- ● Observing
- ● Communicating
- ● Comparing
- ○ Ordering
- ○ Making models
- ● Measuring
- ○ Recording
- ○ Interpreting data
- ● Experimenting
- ○ Predicting
- ○ Hypothesizing
- ● Inferring
- ○ Categorizing or classifying
- ● Recognizing relationships
- ○ Controlling variables

Ohio Science Proficiency Outcomes

(Refer to Appendix D, pp. 335-337, for a description of each outcome.)

6th Grade	9th Grade	12th Grade
1 ●	1 ○	1 ○
2 ○	2 ●	3 ○
3 ●	3 ○	4 ●
4 ○	4 ●	5 ○
5 ●	8 ○	8 ○
6 ○	9 ○	12 ○
7 ○	10 ●	
8 ○	11 ○	
9 ●	12 ○	
10 ○	17 ○	
	19 ○	

Vocabulary

Assemble
Ton
Orientation
Dock
Skid
Pallet
Visualize

Materials

Refer to each activity for the needed materials.

Learning Activity 1

Have learners improve their spatial orientation by encouraging them to do some of the following activities:

- Engaging in physical activities (e.g., frisbee, volleyball, tennis, billiards, dancing, tumbling, parallel parking, and driving in reverse)
- Playing electronic games
- Reading maps
- Envisioning the entire landscape when driving—including where a curve is going and what lies ahead.
- Listening to music (According to research, the more children listen to music, the better they are at visualization.)
- Playing board games

Learning Activity 2

Bring to class samples of everyday boxes in a flat, folded state. For example, boxes from cereal, rice, crackers, and/or butter can be folded flat for demonstration. Instructors may use these in a variety of ways in the classroom (e.g., matching games).

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Learning Activity 3

Instruct each learner to draw a flat box from a sample box and compare their drawings to the actual unfolded box.

Learning Activity 4

Discuss home moving. Ask learners to describe the problems that can occur when packing a truck (e.g., loads that are uneven from back to front and/or from top to bottom). Discuss issues involved in loading a truck evenly, including protecting items in the truck and preventing accidents while driving. (NOTE: Some U-haul trucks have air suspension so that an uneven load will ride more smoothly.)

Learning Activity 5

Discuss the following: You are loading a truck to move to a new house. You have a refrigerator, an empty dresser, and various boxes of clothes and other miscellaneous items. Which will you load into the truck first? Why?

Learning Activity 6

Ask learners to consider how large trucks are loaded to balance the industrial parts they carry. Have learners work in pairs to determine the best way to load three trucks that have crates that weigh the amounts indicated below. Encourage them to make a diagram of their recommendation for each truckload.

NOTE: A balanced truck (close-to-equal weight on both sides) provides better protection to the product and a safer vehicle on the road.

Truckload A	Truckload B	Truckload C
1000 lb	1000 lb	1000 lb
1000 lb	500 lb	500 lb
500 lb	250 lb	250 lb
	1.5 tons	

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Problem

You are an employee working in the shipping department on the shipping dock. You are instructed to package a 3″x 6″x 2′ part into a carton. It can go into the carton in any way. You are asked to find the carton that will result in the least wasted space and to assemble it to pack the part. Cartons are stacked flat for storage. You are to add this box to the balance of the day's production. You are then to load the truck. You have 10 skids to load. They are all the same size, but they are different weights. The skids will fill a truck when stacked 2 skids wide and 5 skids deep. A truck backs into the dock, ready to load. You must determine which size of box to use and the best method for loading the truck.

Identify the Problem

1. What is your assignment?
   - A. You must order cartons from the supplier.
   - B. You are to direct customers to the back room.
   - C. You are to package a part.
   - D. You must find and assemble a carton, pack a part, and load a truck.
   - E. You must operate a forklift and train a helper in its use.

Define the Problem

2. What do you need to consider when completing your assignment?
   - A. You must assemble a carton to accommodate a 3″ x 6″ x 2′ part and send it abroad.
   - B. You need to determine the exact size of the carton, load a skid, and complete the shipping label.
   - C. You must locate and assemble a carton of the proper size, pack the part, and load a balanced truck.
   - D. You must load a truck for shipping.
   - E. You must contact the shipping department before loading the truck.

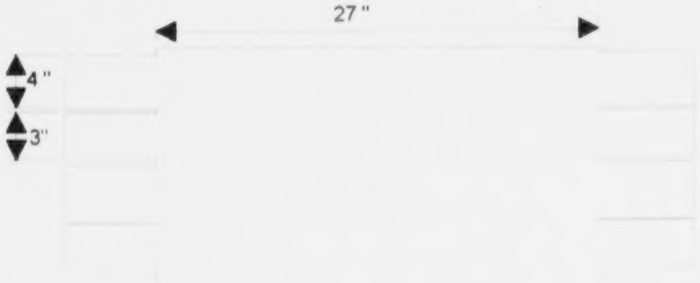
Explore Alternatives

3. Which sequence of events will help you achieve your goal?
   - A. Change the 2′ to 24″; locate the appropriately sized box; assemble the carton; pack the item in the carton; and add the box to the last skid.
   - B. Select a carton; package the part; arrange the skids so that the weights are balanced on each side of the truck; and load the truck.
   - C. Change the 2′ to 24″; give the part to a helper to pack; and load the truck.
   - D. Put all the dimensions in the same denomination; select a flat carton that, when assembled, will accommodate the part; assemble the carton and pack the part; add the carton to the day's production; and load the skids so that the weights are balanced on each side of the truck.
   - E. Wrap the part in brown paper; and load the truck with the skids in numerical order.

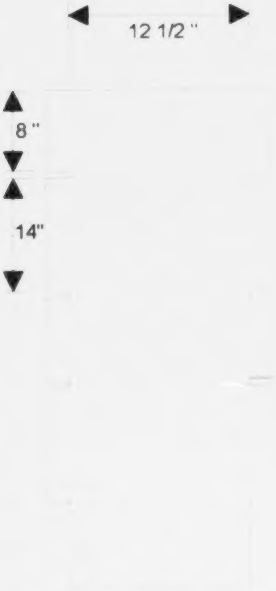
Act on a Plan

4. From the choices below, select the MOST appropriately sized box and assemble it by folding on the creased lines.
   - A. Box A is the best box to use.
   - B. Box B is the best box to use.
   - C. Box C is the best box to use.
   - D. Box D is the best box to use.
   - E. None of the boxes is the right size.

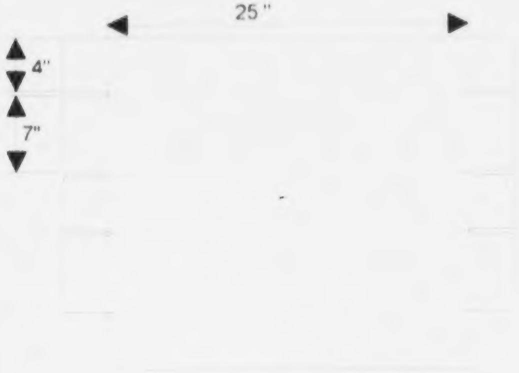
A



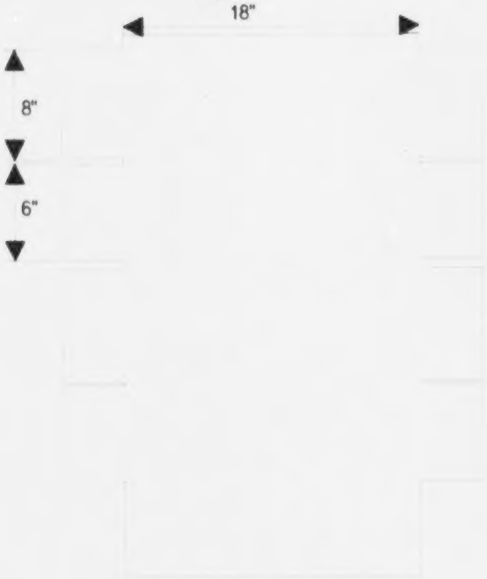
B



C



D



5. From the following, select the MOST appropriately arranged configuration to load into the truck.
   A. Truckload A is best.
   B. Truckload B is best.
   C. Truckload C is best.
   D. Truckload D is best.
   E. None of the configurations will work.

Truckload A		**Truckload B**		**Truckload C**		**Truckload D**	
Left side	Right side	Left side	Right side	Left side	Right side	Left side	Right side
1.5 tons	1000 lb	500 lb	1000 lb	250 lb	500 lb	500 lb	250 lb
500 lb	1000 lb	1000 lb	1.5 tons	1000 lb	500 lb	1000 lb	1000 lb
500 lb	1000 lb	500 lb	500 lb	1000 lb	500 lb	250 lb	500 lb
250 lb	1000 lb	1000 lb	250 lb	1000 lb	1.5 tons	500 lb	1000 lb
250 lb	500 lb	1000 lb	250 lb	1000 lb		1.5 tons	1000 lb
				250 lb			

Look at the Results

6. Does the item fit into the box?
   A. Yes, the part fits into the box.
   B. No, the part is too big for the box.

7. How can you determine whether the truck is loaded in a balanced manner?
   A. Load only the center of the truck, and leave the sides empty to ensure balance.
   B. Visually inspect the truck to see whether it leans to one side.
   C. No check is necessary since truck driver is responsible for that.
   D. Drive the truck to a weigh station on the highway and weigh the truck.
   E. Add up the total weights on each side of the truck.

Mechanics Problem 5.8

Answers

Answers

1. D
2. C
3. D
4. C
5. A
6. A
7. E

Instructor's Notes:

Instructional Support Materials

Mechanics

Mechanics Problem 5.9: Pellet-Transfer System

Scientific Principle

This section focuses on helping learners identify the logical cause for mechanical failure of a conveyor system. It also helps learners identify the best course of action to fix a mechanical problem and to examine the effectiveness of their work.

Background

Learners often have difficulty seeing the relationship of one component to an entire mechanical system. This problem leads learners to an understanding of the effect of temperature changes on the functioning of a mechanical system.

Key Process Skills

(Refer to p. 24 for a description of each process skill.)

●	Observing
●	Communicating
●	Comparing
○	Ordering
○	Making models
●	Measuring
○	Recording
●	Interpreting data
○	Experimenting
●	Predicting
○	Hypothesizing
●	Inferring
○	Categorizing or classifying
●	Recognizing relationships
○	Controlling variables

Ohio Science Proficiency Outcomes

(Refer to Appendix D, pp. 335-337, for a description of each outcome.)

6th Grade	9th Grade	12th Grade
1 ○	1 ○	1 ○
2 ●	2 ●	3 ○
3 ●	3 ●	4 ●
4 ○	4 ●	5 ○
5 ●	8 ●	8 ○
6 ●	9 ○	12 ○
7 ○	10 ○	
8 ○	11 ○	
9 ●	12 ○	
10 ○	17 ○	
	19 ●	

Vocabulary

Conveyor
Pan conveyor
Drive
Gear alignment
Key
Vibration
Shaker drive

To solve Level 5 mechanical problems, learners must be able to see how different parts of the system work together. They must be able to see how factors such as temperature and air flow have on the safe and efficient operation of equipment. To help learners understand how different components of mechanical systems work together, and how each can provide input about the effective operation of the whole, guide them through the some or all of following activities.

Materials

Refer to each learning activity for needed materials.

Learning Activity 1

Find a complex mechanical system in your building or surrounding area (e.g., car, hot water system, building heating system). Have learners analyze how it works. Have them infer what would happen if one component of the system breaks down. Have learners discuss what they would check first to *determine the cause* of a malfunction and *what to do* once the know the reason for the malfunction. Refer to the list of questions about analyzing a system, which is on page 19-21.

Facilitate a discussion during which learners are asked to summarize what they learned.

Learning Activity 2

Have learners work individually or in pairs to design a system that has a specific purpose in a manufacturing process. Have them describe the purpose of each component of the system.

Facilitate a discussion during which learners are asked to summarize what they learned.

Problem

A long pan is used to convey pellets a horizontal distance—from the silo to the hoppers. The pan vibrates to move the contents. The vibration is set up by an attached vibrating shaker drive. This drive rotates weights in opposite directions by gearing. Alignment of the gearing is held by keys in keyways in the driveshaft. The driveshaft is driven by an electric motor. The side of the conveyor has a "V" symbol mounted on it, which indicates the degree of horizontal vibration. The technician determines the degree of horizontal vibration by observing the visual overlap of the sides of the "V" while the conveyor is moving.

You are the technician responsible for making sure that the pellet-transfer system operates properly. You observe that the conveyor is vibrating but it is not moving the pellets. You need to determine why the contents are not being moved.

NOTE TO THE INSTRUCTOR: There is no diagram provided with this problem. This gives learners an opportunity to draw a diagram that fits the description provided in the problem. Diagrams may be drawn individually, in groups, or as a whole class.

Identify the Problem

1. What is your assignment?
   - A. To clean the conveying pan
   - B. To check the drive motor load
   - C. To find out why the material does not convey
   - D. To replace the vibrating conveyor with a belt
   - E. To replace the conveying pan

Define the Problem

2. How can the problem be described?
   - A. The motor does not run.
   - B. The conveyor does not vibrate.
   - C. The motor runs too fast.
   - D. The conveyor vibrates, but the material does not move.
   - E. The motor runs too slowly.

Explore Alternatives

3. What are the possible causes?
   - A. The conveyor is vibrating improperly.
   - B. The drive motor is burned up.
   - C. The conveyor is too long.
   - D. The conveyor is too short.
   - E. The drive motor stopped.

Act on a Plan

4. What would you do to check to see if the vibration has been disrupted?
   - A. Check the motor load.
   - B. Check the moisture of the contents.
   - C. Measure the length of the conveyor.
   - D. Check the shaker drive's mounting; verify that both weights are rotating in opposite directions.
   - E. Check the motor rpm.

Look at the Result

7. You found one weight rotating; the other weight sheared its key and is not moving. What would you do?
   - A. Replace the motor.
   - B. Lubricate the bearings; spin the driveshaft.
   - C. Dry the pan contents; replace the pan.
   - D. Replace the sheared key; check vibration and material movement.
   - E. Check the vibration of the pan.

Answers

1. C
2. D
3. A
4. D
5. D

Instructor's Notes:

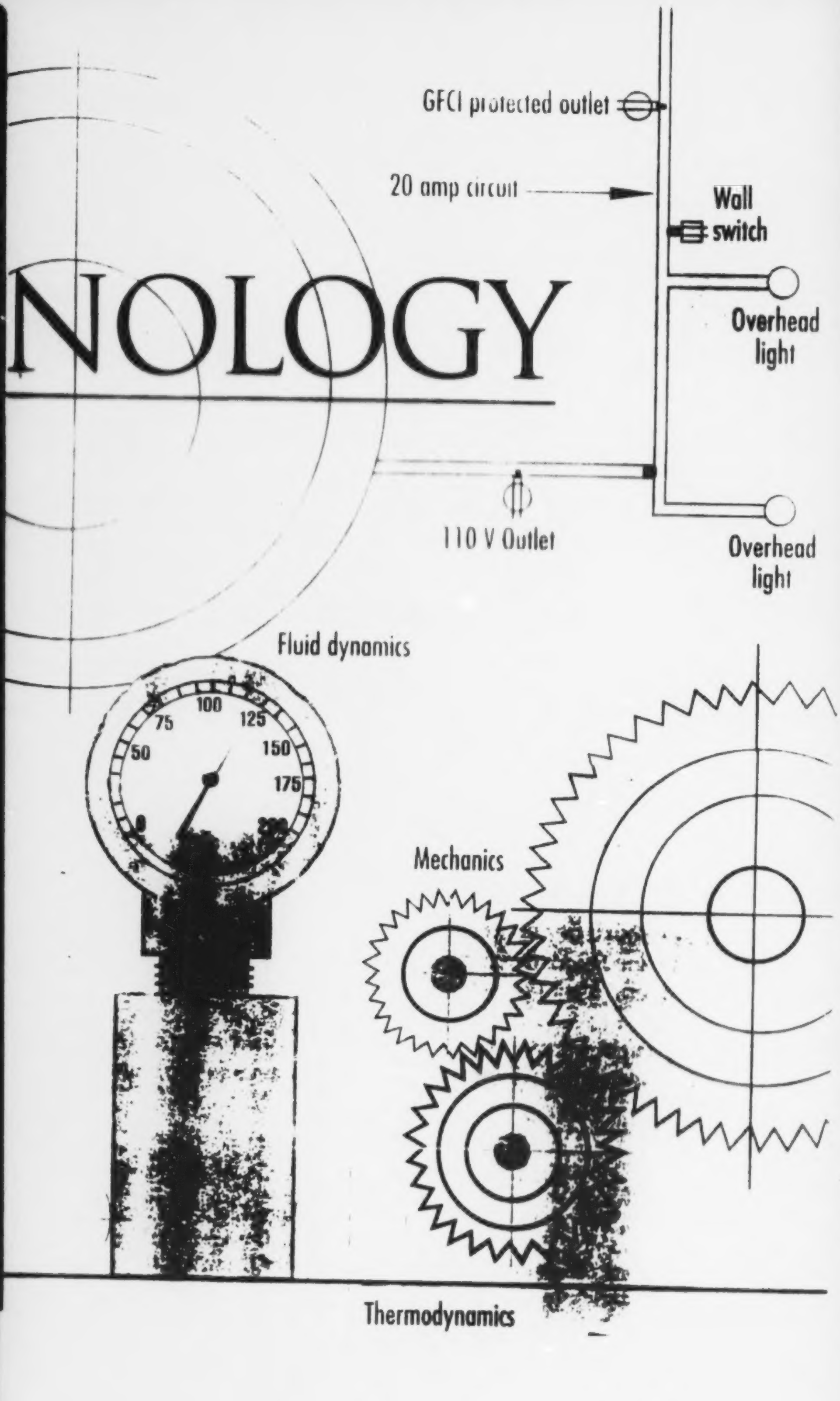
APPLIED TECHNOLOGY

TARGETS FOR LEARNING

LEVEL 6 LEARNING ACTIVITIES AND PROBLEMS

The learning activities and problems in this section are designed to help learners reach applied technology Level 6.

> *"You can tell learners something and they may or may not believe you. But when you actually show it to them, it really seems to sink into their minds."*
>
> Pilot Instructor


GFCI protected outlet
20 amp circuit
Wall switch
Overhead light
110 V Outlet
Overhead light
Fluid dynamics
100
75
125
50
150
175
0
200
Mechanics
Thermodynamics

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Improving to Level 6

As defined and measured by Work Keys, Level 6 learners can

- Use the principles of mechanics, electricity, fluid dynamics, and thermodynamics in advanced applications (e.g., air-conditioning units, automobile hydraulic lifts, reconfiguring wiring, and making modifications on a bicycle with two sprockets to maximize performance).
- Use subtle, less visible clues to determine the source of the problem with a machine or tool. (Information is gathered by sight, sound, smell, experience, etc.)
- Troubleshoot complex systems in which a variety of mechanical, electrical, flow, or thermal faults are potential sources of difficult problems.
- Choose the appropriate tool or piece of diagnostic equipment to accomplish a certain task.

The learning activities in this section are designed to help learners reach applied technology Level 6. In addition, to the presenting these, instructors may wish to use some of the books, software, and materials described in the Resource list, pp. 307-325, to—

- Gain a clearer understanding of the basic scientific principles involved in applied technology problems
- Select activities to supplement those in Targets for Learning
- Recommend resources to learners wishing to gain deeper insights about the basic scientific principles involved in applied technology problems

Improving to Level 6 **Index**

Problem Number	Category	Problem Topic	Page Number
6.1	Thermodynamics	Car Air Conditioner	267
6.2	Fluid Dynamics	Cooling System With Tank	275
6.3	Electricity	Control Wiring and Conduit Layout	285
6.4	Mechanics	Conveyor Belt With Pulleys	295

Instructional Support Materials

Thermodynamics Problem 6.1: **Car Air Conditioner**

Scientific Principle

This problem involves the principles of latent heat, evaporation, condensation, and change of state.

Background

A car's air-conditioning system takes refrigerant from the gas phase to the liquid phase and returns it back to a gas. Each time the refrigerant changes state, heat is either absorbed or released.

Key Process Skills

(Refer to p. 24 for a description of each process skill.)

●	Observing
●	Communicating
●	Comparing
○	Ordering
○	Making models
●	Measuring
●	Recording
●	Interpreting data
●	Experimenting
○	Predicting
○	Hypothesizing
○	Inferring
○	Categorizing or classifying
●	Recognizing relationships
○	Controlling variables

Ohio Science Proficiency Outcomes

(Refer to Appendix D, pp. 335-337, for a description of each outcome.)

6th Grade	9th Grade	12th Grade
1 ●	1 ○	1 ●
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4 ●	4 ●	5 ●
5 ○	8 ○	8 ○
6 ○	9 ○	12 ○
7 ○	10 ●	
8 ●	11 ○	
9 ●	12 ○	
10 ●	17 ○	
	19 ○	

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Vocabulary

Psi (pounds per square inch)
Refrigerant
Expansion valve
Ohmmeter
Thermostat switch
Evaporator
Compressor
Condenser
Pressure gauge
Compressor clutch

NOTE: The activities suggested in this section require more specialized equipment and resources than are readily available to many instructors. The instructor is encouraged to refer to the books described in the Resource section, pp. 307-319, and to speak with an automotive maintenance or heating/air conditioning teacher at your local vocational school.

Materials

Air conditioning system of a car—actual or table-top demonstration
Diagrams of various air conditioning systems (e.g., cars, houses) (One diagram is provided in this problem.)
Electrical meters (e.g., ohmmeter)
Several types of pressure gauges
Worksheet on reading electrical meters

To acquaint learners with cooling systems, instructors can provide them with the following learning opportunities.

Learning Activity 1

Have learners examine an actual air-conditioning system. Have them identify the components of the system. Then have them track the flow of refrigerant, identifying the changes of state and where heat is absorbed and released.

Provide learners with diagrams of air conditioning systems. Have them trace the flow of refrigerant through the air conditioner.

Learning Activity 2

Demonstrate how pressure gauges work. Have learners work in pairs to practice operating and reading several different pressure gauges. To do this, they can take readings on actual equipment.

Learning Activity 3

Demonstrate how ohmmeters are used to measure voltage, ohms, amps, and continuity. Have learners practice making measurements.

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Problem

A customer brings in a car and says that the air conditioner is not working. Specifically, on hot days it does not get cool enough. The customer had the car's air-conditioning system recharged within the last week. There is also a clicking sound coming from under the hood. Your supervisor asks you to diagnose the problem and suggest a solution. Refer to Diagram 6.11 to answer the questions that follow.

Identify the Problem

1. What have you been asked to do?
   - A. Determine why the air conditioner is not working properly.
   - B. Determine why the car is overheating.
   - C. Determine why the air conditioning is not working properly and discuss it with your supervisor.
   - D. Fix the air-conditioning system.
   - E. Recharge the air-conditioning system.

Define the Problem

2. The problem in the system could be that
   - A. The blower motor on the evaporator is not working.
   - B. The magnetic clutch is not engaging properly.
   - C. The refrigerant level is low.
   - D. The condenser is clogged.
   - E. The fan belt is broken.

3. To identify the cause of the malfunction, you would NOT need to
   - A. Check the coil in the magnetic clutch.
   - B. See if the filter in the accumulator dryer is clogged.
   - C. Check the coolant thermostat.
   - D. Inspect the temperature-sensing bulb.
   - E. Check the fan belts.

Explore Alternatives

4. To isolate the problem, you would FIRST
   - A. Check the magnetic-clutch coil.
   - B. See if the blower-motor evaporator is running.
   - C. Check for a clogged expansion valve.
   - D. Check for a loose accumulator dryer.
   - E. Check for a refrigerant leak.

Act on a Plan

5. Below are observations made of the system. Which would indicate an existing problem?
   - A. There is a loose belt on the compressor.
   - B. The expansion valve is not clogged.
   - C. There is no continuity in the clutch coil.
   - D. The pressure on the high side is 190 psi; the pressure on the low side is 30 psi.
   - E. The fan belt is frayed.

6. To correct the problem, you would
   - A. Add refrigerant.
   - B. Change the expansion valve.
   - C. Change the compressor.
   - D. Replace the magnetic-clutch coil.
   - E. Replace the refrigerant.

Look at the Result

7. If the problem has NOT been corrected, which of the following would you expect?
   - A. The air-conditioning system has plenty of refrigerant.
   - B. There will be no clicking sound under the hood.
   - C. The air-conditioning system cools the car on cool days.
   - D. The air-conditioning system cools the car on hot days.
   - E. The air-conditioning system needs to be recharged at this time.

The Parts and Function of the Air-Conditioning System

Compressor	Pressurizes refrigerant
Condenser	Changes refrigerant vapor to liquid
Accumulator dryer	Removes moisture and stores extra refrigerant
Expansion valve	Reduces refrigerant pressure before it enters the evaporator
Compressor clutch	Allows the compressor to turn when it is engaged
Thermostat switch	Engages the clutch

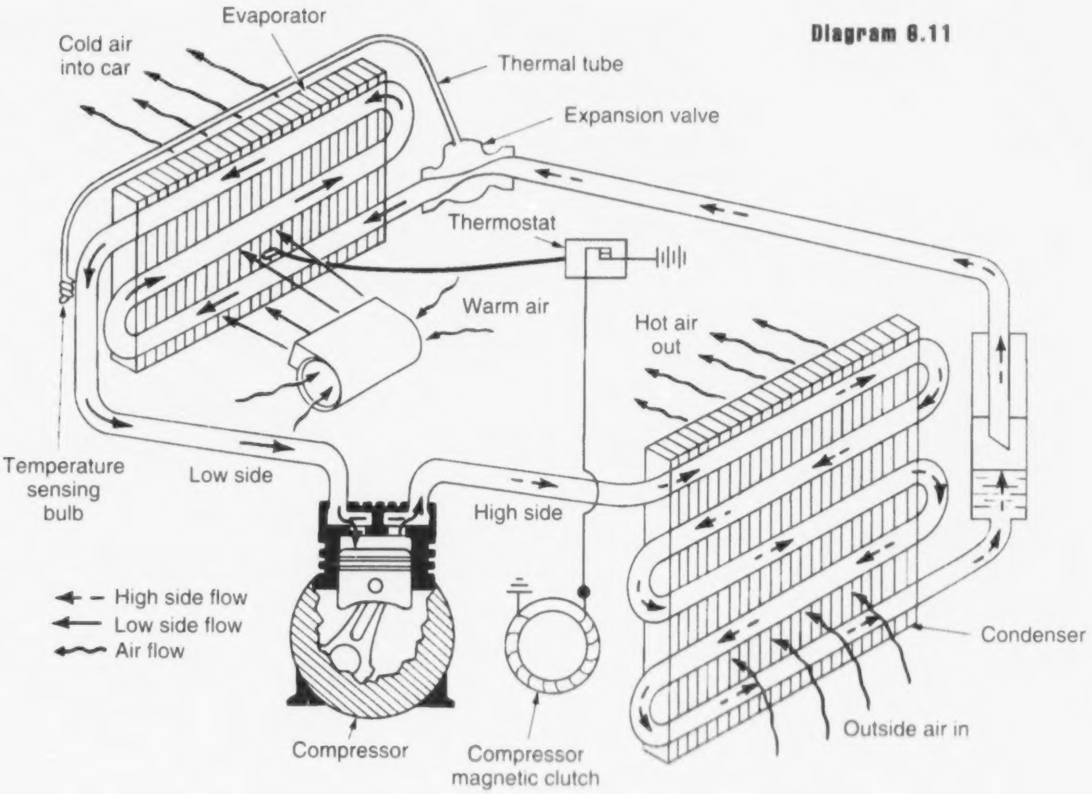

Diagram 6.11

Evaporator
Cold air into car
Thermal tube
Expansion valve
Thermostat
Warm air
Hot air out
Temperature sensing bulb
Low side
High side
High side flow
Low side flow
Air flow
Condenser
Outside air in
Compressor
Compressor magnetic clutch

This diagram was provided by and used with the permission of Deere & Co.

Answers

1. C
2. B
3. C
4. A
5. C
6. D
7. E

Instructor's Notes:

Instructional Support Materials

Fluid
dynamics

Fluid Dynamics Problem 6.2: **Cooling System With Tank**

Scientific Principle

The primary principles involved in this problem are flow rate of liquids, pulley systems, and open systems.

Background

Flow rate is equal to volume divided by time (i.e., $Q_v = V/t$). Fluids will flow from a place of high pressure to a place of low pressure. An electric motor or the force of gravity can provide the high-pressure area. Fluid will flow along any path that is available to it. Large-diameter pipes have low pressure. Smaller-diameter pipes have greater pressure. Net flow is equal to the input flow minus the output flow. When fluid resistance is reduced, flow rate is increased if the pressure is constant. Fluids are typically noncompressible.

Key Process Skills

(Refer to p. 24 for a description of each process skill.)

●	Observing
●	Communicating
●	Comparing
◐	Ordering
◐	Making models
●	Measuring
●	Recording
●	Interpreting data
●	Experimenting
◐	Predicting
◐	Hypothesizing
◐	Inferring
●	Categorizing or classifying
●	Recognizing relationships
●	Controlling variables

Ohio Science Proficiency Outcomes

(Refer to Appendix D, pp. 335-337, for a description of each outcome.)

6th Grade	9th Grade	12th Grade
1 ●	1 ●	1 ●
2 ●	2 ◐	3 ●
3 ◐	3 ●	4 ●
4 ●	4 ●	5 ◐
5 ●	8 ●	8 ◐
6 ◐	9 ●	12 ◐
7 ●	10 ●	
8 ◐	11 ◐	
9 ◐	12 ◐	
10 ◐	17 ◐	
	19 ●	

Vocabulary

Driven pulley
Driving pulley
Flow rate
Pressure
Diameter
Meter
Volume
Gravity
Horsepower
Pump
Cooling system
Cooling tank
Systems check

Learning Activity

Flow Rates and Pressure

Materials

Plastic or tin containers with various sizes and shapes of holes
A bucket or sink

Have learners work in pairs. Help them take the steps that are described on Worksheets 6.21 and 6.22. (An answer sheet is provided for instructors.)

Fluid Dynamics Problem 6.2 Worksheet 6.21

Flow Rates and Pressure

1. Predict what will happen when a container that has four equal-sized holes punched in its side (see Diagram 6.21) is filled with water. Then fill the can with water and observe the water flowing from each hole. Note which hole delivers water the farthest. Record your observations below.

Prediction:

Observation:

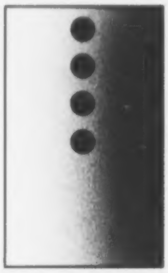

Diagram 6.21

2. Predict what will happen when water is poured into two cans, each of which has one hole that is sized differently from that in the other can (e.g., a 1/4") hole in one can and a 1/8" hole in the other can) but that is positioned at the same height (see Diagram 6.22). Then, pour water into the two cans and observe what happens. Note which can delivers the water the farthest. Record your observations below.

Prediction:

Observation:

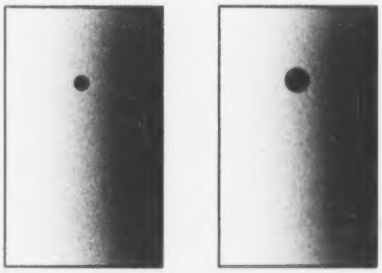

Diagram 6.22

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3. Predict what will happen when two different liquids are poured into two cans, each of which has a same-sized hole (e.g., 1/4″) placed at the same height (see Diagram 6.23). Then place oil in one can and water in the other can. Note which liquid is delivered farthest. Record your observations below.

Prediction: ______________________________

____

Observation: ______________________________

____

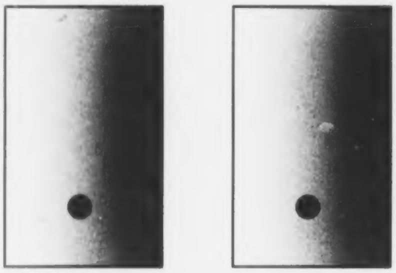

Diagram 6.23

4. Perform the tasks described in this worksheet again. This time, measure the flow rate from each of the cans by collecting the fluids in separate containers as they leave the cans. The time must be held constant for each experiment.

5. In the space below, summarize what you learned about flow rate and pressure.

____

____

____

____

____

____

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Solving Fluid Flow Rate Problems

Facts: Volume flow rate = Volume displaced divided by elapsed time ($Q_V = V/t$)
Net flow rate=Input rate minus the output rate
4 quarts = 1 gallon
60 minutes = 1 hour

1. If 200 gallons of fluid are delivered into a reservoir in 14 minutes, what is the flow rate?

2. A hose delivers water into a fountain at a rate of 0.75 gal/min. The water flows from this fountain to other components at a rate of 0.25 gal/min. What is the net flow into the fountain?

3. A 150-gallon water tank can be filled at a flow rate of 3 gal/min. How long will it take to fill the tank?

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Fluid Dynamics Problem 6.2 Answer Sheet

Flow Rate and Pressure

1. Predict what will happen when a container that has four equal-sized holes punched in its side (see Diagram 6.21) is filled with water. Then fill the can with water and observe the water flowing from each hole. Note which hole delivers water the farthest.

   Answer: The lowest hole will have the greatest distance due to greater pressure.

2. Predict what will happen when water is poured into two cans, each of which has one hole that is sized differently from that in the other can but that is positioned at the same height. Observe the water flow from two cans. Note which can delivers water the farthest.

   Answer: The can with the smaller hole will have the greater distance because of greater pressure.

3. Predict what will happen when two different liquids are poured into two cans, each of which has a same-sized hole placed a the same height. Observe the flow of liquids the two cans. Note which liquid is delivered farthest.

   Answer: Because it is less dense, the water will travel a greater distance than the oil.

Solving Fluid Rate Problems

Facts: Volume flow rate = Volume displaced divided by elapsed time (Qv =V/t).
Net flow rate=Input rate minus the output rate.
4 quarts = 1 gallon
60 minutes = 1 hour

1. If 200 gallons of fluid are delivered into a reservoir in 14 minutes, what is the flow rate?

   Answer: Qv=V/t = 200 gal/14 min=14.29 gal/min

2. A hose delivers water into a fountain at a rate of 0.75 gal/min. Water flows from this fountain to other components at a rate of 0.25 gal/min What is the net flow into the original fountain?

   Answer: Net flow rate =0 .75 gal/min - 0.25 gal/min = 0.5 gal/min

3. A 150-gallon water tank can be filled at a flow rate of 3 gal/min. How long will it take to fill the tank?

   Answer: t= V/Qv = 150 gal/ 3 gal/min = 50 min

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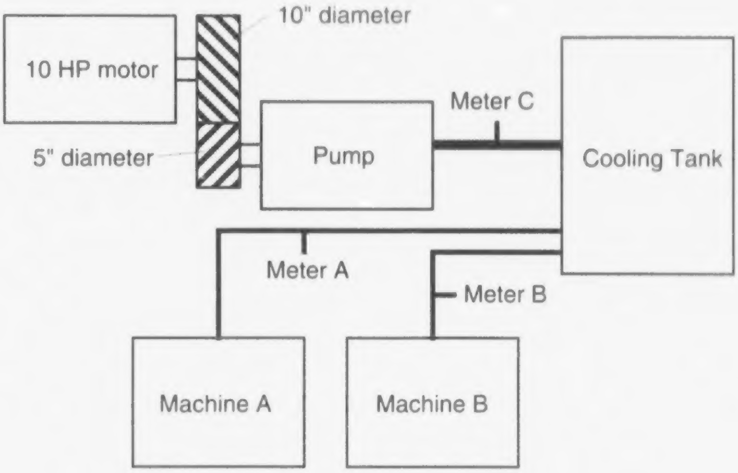
Problem /

At your place of employment, the cooling system has a 10-horsepower motor running a positive displacement pump at twice the speed of the motor. (See the diagram below.) The motor uses a 10″ driving pulley and a 5″ driven pulley. This system is supplying a 32-quart cooling tank that is 3′ tall. This tank supplies two machines. The tank is 33% full. It takes 250 minutes to finish filling the tank. Your systems operator asks you to run a systems check. You find that the flow meter readings are accurate and you get the following readings:

Meter	Flow Rate (gal/hr)
A	1
B	.5
C	3

It is your responsibility to analyze the system and report to the systems operator.


10" diameter
10 HP motor
Meter C
Cooling Tank
5" diameter
Pump
Meter A
Meter B
Machine A
Machine B

Identify the Problem

1. What is your assignment?
   A. To evaluate the systems
   B. To determine whether the system is outdated
   C. To determine whether the horsepower of the motor is correct
   D. To repair the system
   E. To clean the cooling tank

Define the Problem

2. What do you need to do to evaluate this system?
   A. Replace the pump.
   B. Clear the lines of any clogs or blockages.
   C. Calculate the expected flow rate as compared to the meter readings.
   D. Calculate the wattage of the motor.
   E. Determine the gear ratio between the motor and the pump.

Explore Alternatives

3. What factors could account for the discrepancy between the actual flow rate and the meter readings?
   A. The belt on the pulley is slipping.
   B. The cooling tank is not level.
   C. The pump is not running properly.
   D. There is a leak ahead of Meters A and B.
   E. There is a leak in Machine A and/or B.

Act on a Plan

4. What is the BEST thing for you to do with this information?
   A. Report to the systems operator that one of the machines is leaking.
   B. Replace the motor.
   C. Report to the systems operator that the system is functioning properly.
   D. Report to the systems operator the exact location of the leak in the line.
   E. Change the speed of the pump to increase the fill rate to the cooling tank.

Look at the Result

5. After you gave the report to your systems operator, a certified repair person sealed the leak in the cooling tank. How will you verify that the system is operating properly?
   A. Recalculate the flow rate for the cooling tank.
   B. Measure the motor voltage.
   C. Recalculate the motor's horsepower.
   D. Verify that the lines have no blockages.
   E. Recalculate the horsepower for the motor.

Answers

1. A
2. C
3. D
4. D
5. A

Instructor's Notes:

Instructional Support Materials

Electricity Problem 6.3: Control Wiring and Conduit Layout

Scientific Principle

This problem focuses on using a control-wiring diagram and a conduit layout to determine the wires in various runs of conduit. Once the wires are determined for the various runs of conduit, the *National Electrical Code* (NEC) is used as a tool to size the wires and conduit.

Background

To run conduit and pull wires a person must understand control-wiring diagrams and the *National Electrical Code* (NEC). Entry-level electricians are expected to have this knowledge. The following information will help the instructor determine how to derive the solutions to Problem 6.3.

Wires in conduit: To determine which wires are in each section of the conduit, the instructor needs to understand wiring diagrams, ladder logic, and conduit layouts. Someone who is not experienced in determining which wires are in the various sections of the conduit can use the following strategy to solve this type of problem:

- Locate the various control devices on the conduit layout.
- At each control device, identify which wires terminate at that device and get the wire number from the control diagram.
- Connect the wire numbers, and you have the various control wires identified for each section of conduit.

Wire sizing and conduit sizing using the NEC: The worksheet furnished with Problem 6.3 requires fill-in-the-blank information that comes from various sources. The following is a walk through of the worksheet (using NEC references from the 1996 Code):

- Wire to be used, THW, comes from the wiring diagram and conduit layout.
- The number of motors and the motor horsepower come from the data given in the conduit layout.
- The motor amps come from Table 430-150, page 70-456 of the NEC. Given on the wiring diagram and the conduit layout motors are 3 phase 480 volt. For 480 volts, the 460 figures are used.
- The 125% is a down-rating of the wires. This information is found on page 70-424 of the NEC. Section 430-22 covers this down-rating. (The higher amp rating causes the down-rating by requiring the wire to handle a higher-than-necessary amperage.)

- Wire sizes are from Table 310-16 on page 70-191 of the NEC. It is important that the reader considers the footnotes.
- Wire cross-sectional area is from Table 5, which begins on page 70-883 of the NEC.
- Conduit size comes from page 70-881 on Table 4 of the NEC. Rigid-metal conduit was given, and fill of 40% must be used because there are more than 2 wires in the conduit.

Key Process Skills

(Refer to p. 24 for a description of each process skill.)

○	Observing
●	Communicating
○	Comparing
○	Ordering
○	Making models
○	Measuring
○	Recording
●	Interpreting data
○	Experimenting
○	Predicting
○	Hypothesizing
●	Inferring
○	Categorizing or classifying
●	Recognizing relationships
○	Controlling variables

Ohio Science Proficiency Outcomes

(Refer to Appendix D, pp. 335-337, for a description of each outcome.)

6th Grade	9th Grade	12th Grade
1 ●	1 ●	1 ●
2 ●	2 ○	3 ○
3 ●	3 ●	4 ○
4 ●	4 ●	5 ○
5 ●	8 ○	8 ○
6 ○	9 ○	12 ○
7 ○	10 ●	
8 ●	11 ○	
9 ●	12 ○	
10 ○	17 ○	
	19 ●	

NOTE: The activities suggested in this section require more specialized equipment and resources than are readily available to many instructors. You are encouraged to refer to the books described in the Resource section, pp. 307-319, and to speak with a vocational instructor who teaches electrical wiring at your local vocational school.

Material for Each Group of Learners

Control wiring diagrams
Assorted conduit
Assorted wire
Ohmmeters

Learning Activity 1

Provide learners with opportunities to practice using control wiring diagrams and conduit layout to determine the wires in various runs of conduit. They should also practice using the NEC to size the wires and the conduit. By doing this, they will also be practicing problem solving.

Learning Activity 2

Repeat the electricity-related learning activities suggested in Levels 4 and 5, but make the problems more complicated. For example, have learners do the following:

- Build circuits that include motors or thermostats from a given circuit diagram.
- Experiment with those circuits to see how they are used.
- Select and use gauges and ohmmeters to check the effectiveness of electrical systems and components in those systems (e.g., fuses).
- Use ohmmeters to test the operation of devices.

Learning Activity 3

Have the learners examine and sketch the wiring in their kitchens. Then have them work in pairs to design a kitchen that includes switches, outlets, and fuses that provide ground fault interruption to protect against too great a load on the circuit.

REMEMBER: Level 6 problems should include complex systems, present extraneous information, and should indicate no one clear path to a solution.

Problem

As an electrician, you are given the control wiring diagram and conduit layout that follow the questions to this problem. You are to pull the minimum number of wires—properly sized and numbered—in each run of conduit. Each run of conduit is to be properly sized to handle the wires. Before starting the job, to make sure you know what you are doing, your supervisor has asked you to describe your recommendation for the size of Conduit B and the wire number and size of each wire in Conduit B. Use the information in the attached diagram and charts as needed.

Identify the Problem

1. What is your assignment?
   - A. Run one size of conduit for the complete installation
   - B. Tell your supervisor the size of Conduit B and the size and number of wires in it before starting the job
   - C. Complete the job and then tell your supervisor the size of Conduit B and the size and number of the wires in it
   - D. Complete the installation with the correct size of conduit, ans size and number of wires. Report to your supervisor.
   - E. Tell your supervisor the size of Conduit B and the size and number of the wires in it and the job is done

Define the Problem

2. Before starting this installation, what is the information the supervisor wants from you?
   - A. The size of all conduits
   - B. The number and size of all wires in the system
   - C. The material list for all items necessary to complete the installation
   - D. The size of Conduit B complete with the wires and their size which are to be pulled in this conduit

Explore Alternatives

3. What is the best approach to solving this problem with Conduit B?
   - A. Since there are 11 control wires and 9 motor wires, run a 1 1/4″ conduit and pull 11 #14 wires for controls and 9 #12 wires for the motor leads. Size the conduit for 20 #12 wires.
   - B. Using the NEC, size the 9 motor leads for the largest motor and pull in this size for all motors and 6 #14 wires for the controls. The conduit should be sized for 12 motor leads. This will allow for the 6 #14 control wires.
   - C. Using the NEC, size the motor leads to carry the full load amperes for each motor and use 11 #16 wires for the controls. The conduit should be sized for 20 #10 wires.
   - D. Pull 20 #14 wires in a 1 1/4″ conduit.
   - E. From the wiring diagram and conduit layout, identify the wires in the conduit and size the wire and conduit using the NEC.

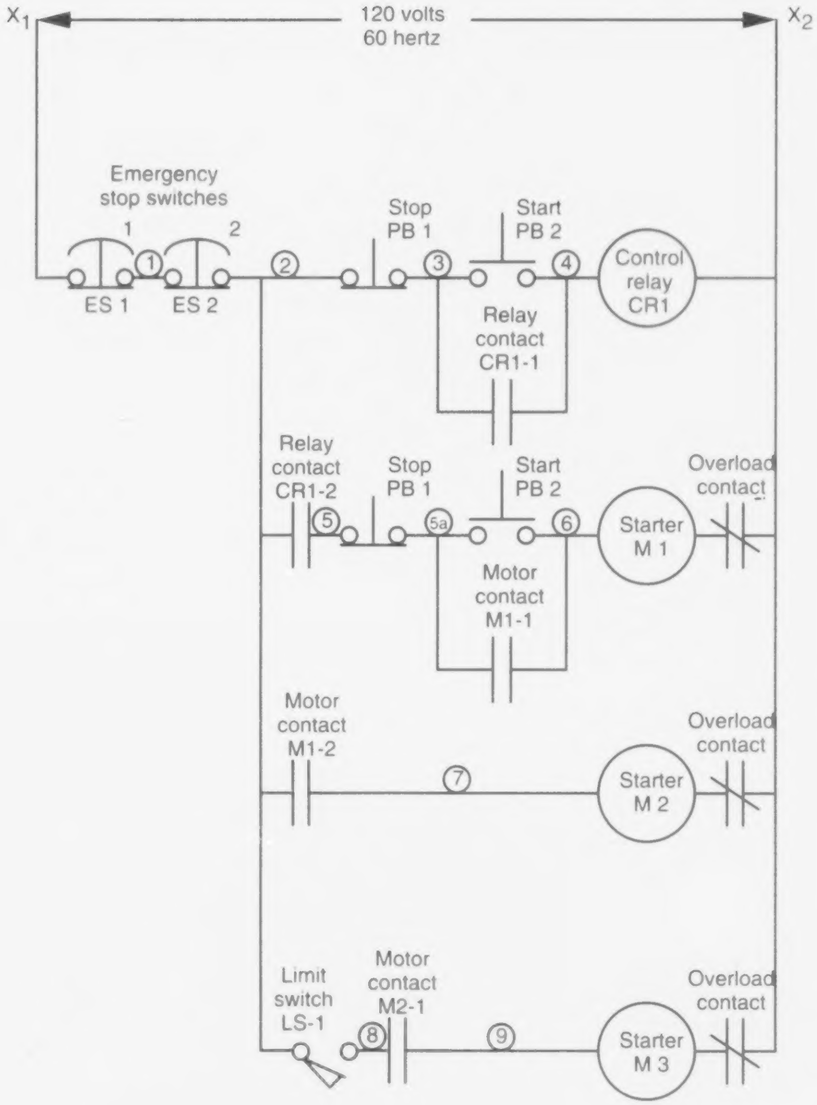
Act on a Plan

4. After you study the wiring diagram and conduit layout, what should your procedure be to determine wire numbers and size for the control and motor wires in Conduit B, including the size of the conduit?
   - A. From the wiring diagram and conduit layout, identify the control wires that will be run in conduit B.
   - B. From the conduit layout, identify the motor wires that would run in Conduit B.
   - C. Using the NEC, size the wires for the control and motor wires.
   - D. Using the NEC, size the conduit for the wires in Conduit B.
   - E. Do all of the above.

Look at the Result

5. Which of the following have you NOT found?
   - A. Five #14 control wires, numbers X1, 2, 5, 6, 8
   - B. Motor 1, 3 #10 wires, numbers T1, T2, T3; Motor 2, 3 #14 wires, numbers T1, T2, T3; Motor 3, 3 #14 wires, numbers T1, T2, T3
   - C. All motor wires #12 with 3 for each motor numbered T1, T2, T3, total of 9 wires
   - D. Conduit size 1″
   - E. All of the above are correct.

Ladder Diagram
Controls


X1
120 volts
60 hertz
X2
Emergency
stop switches
1
2
①
②
ES 1
ES 2
Stop
PB 1
③
Start
PB 2
④
Control
relay
CR1
Relay
contact
CR1-1
Relay
contact
CR1-2
⑤
Stop
PB 1
5a
Start
PB 2
⑥
Starter
M 1
Overload
contact
Motor
contact
M1-1
Motor
contact
M1-2
⑦
Starter
M 2
Overload
contact
Limit
switch
LS-1
⑧
Motor
contact
M2-1
⑨
Starter
M 3
Overload
contact

Electricity Problem 6.3

Worksheet

Conduit Fills

Wire to be Used ____________________

Number of Motors	Motor Hp	Motor Amp	125 %	Wire Size	Number of Wires	Group Motors Per Conduit	Wire Cross-Sectional Area	Total Cross-Sectional Area	Conduit Size

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Worksheet Answers

Electricity Problem 6.3

Wire to be Used THW

Conduit Fills

Number of Motors	Motor Hp	Motor Amp	125 %	Wire Size	Number of Wires	Group Motors Per Conduit	Wire Cross-Sectional Area	Total Cross-Sectional Area	Conduit Size
1	5	7	9.5	14	3		0.0209 X 11 0.2299	0.2299	
1	7 ½	11	13.8	14	3	B	0.0333 X 3 0.0999	0.0999	
1	15	21	26.3	10	3				
								0.3298	1"Q Min
Controls				14	5				
				#14 Wires	Total 11			Code Page 70-881	
				#10 Wires	Total 3				

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Electricity Problem 6.3

Answers

1. D
2. D
3. E
4. E
5. C

Instructor's Notes:

Mechanics Problem 6.4: **Conveyor Belt With Pulleys**

Scientific Principle

The principles involved in this problem include friction, power train (pulley system), and force transformers.

Background

This information can be used in a wide variety of applications, including vibration analysis, manufacturing, drive trains, maintenance, and frictional wearing of machinery.

Key Process Skills

(Refer to p. 24 for a description of each process skill.)

●	Observing
●	Communicating
●	Comparing
◐	Ordering
◐	Making models
◐	Measuring
●	Recording
●	Interpreting data
●	Experimenting
◐	Predicting
◐	Hypothesizing
◐	Inferring
●	Categorizing or classifying
●	Recognizing relationships
◐	Controlling variables

Ohio Science Proficiency Outcomes

(Refer to Appendix D, pp. 335-337, for a description of each outcome.)

6th Grade	9th Grade	12th Grade
1 ◐	1 ◐	1 ●
2 ●	2 ●	3 ●
3 ●	3 ●	4 ●
4 ●	4 ◐	5 ●
5 ●	8 ●	8 ●
6 ●	9 ●	12 ◐
7 ●	10 ◐	
8 ◐	11 ◐	
9 ●	12 ◐	
10 ●	17 ◐	
	19 ◐	

Vocabulary

Power train
Pulley system
Force transformer
Conveyor belt system
Psi (pounds per square inch)

Learning Activity 1

Effects of Friction and Heat

Background

When various materials are rubbed together, a considerable amount of heat is produced due to friction.

Materials

Various materials to rub together, such as rubber tires, concrete block, and different metals.

Procedure

Direct individual learners or learners working in small groups to do the following:

1. Predict what will happen when different materials are rubbed together.
2. Move a piece of rubber tire over a concrete block many times in a short period of time. (This will cause heat to be created.)
3. Try the same process with different materials to observe the generation of heat.
4. Encourage learners to make observations about what has happened and to summarize what they learned about differences in the generation of heat due to different materials used.

Learning Activity 2

Examination of Bearing Types

Background

Different types of bearings are used in different applications to reduce friction. There are advantages to each bearing type and material.

Materials

Scrap bearings of various types (from local auto repair shops)

Procedure

1. Discuss each bearing type, including its use.
2. Have learners work individually or in small groups to experiment with bearings, comparing and contrasting their characteristics and possible uses.
3. Have learners summarize what they learned about bearings, their characteristics, and their uses. If appropriate, have learners make an oral presentation about what they learned.

Learning Activity 3

Construct a Multiple Pulley Drive System

Background

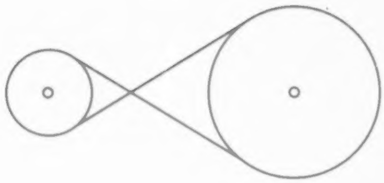
The larger-diameter pulley will rotate less often and the smaller-diameter pulley will rotate more often. You can compare the rpm of each pulley to the ratio of the pulley diameter.

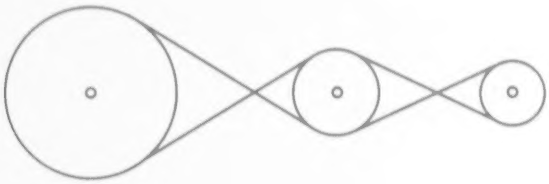
Materials for Each Group of Learners

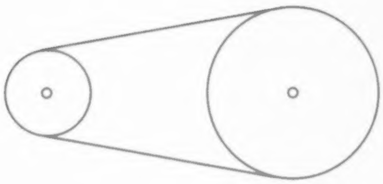
Jar lids of various sizes (e.g., from mayonnaise jars, pickle jars)
Rubber bands
Nails
Wood board

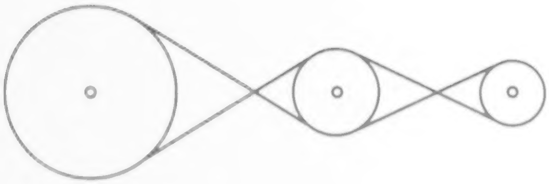
Procedure

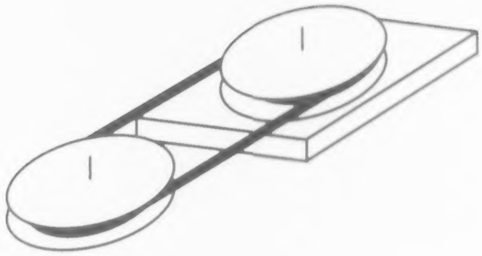
1. Instruct learners, working in groups of 3-4, to build a multiple-pulley drive system by using the materials provided. (See the following diagrams.) Help them to investigate the relationship between pulley diameter and rpms, misalignment, etc. In other words, help them discover how the pulley diameter relates to rpm misalignment. Have learners record their findings.
2. Have learners discuss their observations and experiences.









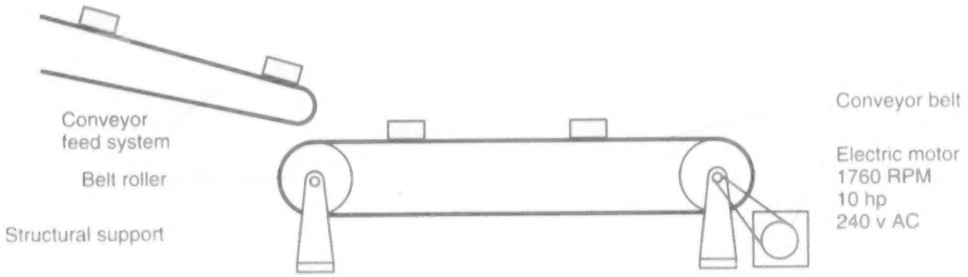


Problem

You are a member of the maintenance department of a small manufacturing facility. Your responsibility is to perform routine maintenance, troubleshoot, and solve equipment malfunctions. The plant contains many conveyor-belt systems of various types. The conveyors transport loads of 50-100 lb loads. One particular conveyor-belt system requires an abnormally high amount of repair as compared to other similar systems. The problem conveyor belt, as shown in the diagram on the following page, is powered by an electric motor. (For clarity, the protective housings are not shown.)

Maintenance personnel report a number of chronic symptoms. It has been observed that the conveyor belt changes speed sporadically and often moves sluggishly. At times, there is an odor of burnt rubber. The drive belt requires replacement more frequently than normal. In addition, the noise level is abnormally high. As the motor speed increases, the noise level increases and the motor overheats.

Your job is to repair the conveyor-belt system so that it meets normal operating conditions. Refer to the following diagram as needed.



Identify the Problem

1. What is your assigned task?
   - A. To lubricate the bearings
   - B. To reduce the conveyor-belt load
   - C. To increase the production rate
   - D. To find the causes of sluggish operation
   - E. To check the motor speed in rpm

Define the Problem

2. What should you base your investigation upon?
   - A. The loads
   - B. Symptoms reported by the maintenance personnel
   - C. The production rate
   - D. The motor speed
   - E. The cost of the repairs

Examine Alternatives

3. What subsystem is most likely responsible for the symptoms observed?
   - A. Electric motor
   - B. Mechanical drive system between the electric motor and the belt roller
   - C. Conveyor belt and rollers
   - D. Conveyor feed system
   - E. Structural support system of the conveyor belt

4. What is the most probable cause of the system's high maintenance?
   - A. The motor speed is too low.
   - B. The belt tension is improper.
   - C. The material load is too great.
   - D. A drive pulley on the motor is misaligned.
   - E. The voltage to the motor is low.

Act on a Plan

5. Considering the reported symptoms, which procedure would you perform FIRST?
   - A. Check the power voltage to the motor.
   - B. Replace the drive belt.
   - C. Lubricate the bearings.
   - D. Replace the belt rollers.
   - E. Check the drive belt's alignment.

Look at the Result

6. You inspected the drive belt system and found it to be misaligned. You realigned the drive-belt system. After realigning the drive belt and pulleys, what would you do to see if the problem is eliminated?
   - A. Restart the conveyor belt.
   - B. Check the conveyor belt tension.
   - C. Check the motor speed.
   - D. Restart the conveyor belt and monitor the system's operation.
   - E. Estimate the production rate.

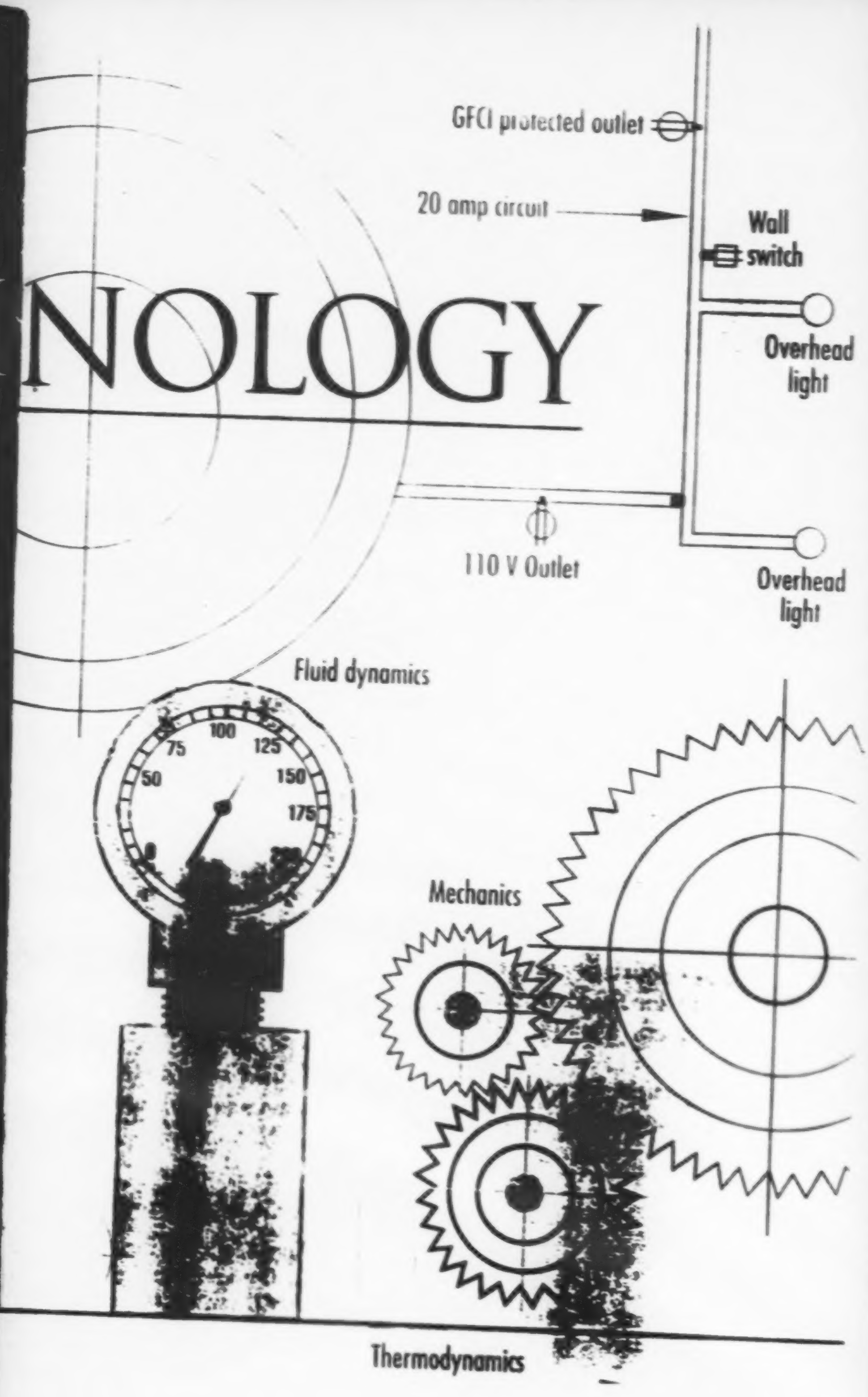
Answers

1. D
2. B
3. B
4. D
5. E
6. D

Instructor's Notes:

APPLIED TECHNOLOGY

TARGETS FOR LEARNING


GFCI protected outlet
20 amp circuit
Wall switch
Overhead light
110 V Outlet
Overhead light
Fluid dynamics
100
75
125
50
150
175
0
200
Mechanics
Thermodynamics

Appendix A References

Appendix B Resources

Appendix C Basic Scientific Principles

Appendix D Ohio Science Proficiency Outcomes

BEST COPY AVAILABLE

289

APPENDIX A

References

Adkinson, S., M. Fleer, eds. (1995). *Science With Reason*. London: Hodder and Stoughton Educational.

American Association for the Advancement of Science (1993). *Benchmarks for Science Literacy: A Project 2061 Report*. New York: Oxford University Press.

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American College Testing Program (1995). *Targets for Instruction, Applied Technology*. Iowa City, IA: ACT.

Bransford, J., B. Stein (1984). *The IDEAL Problem Solver: A Guide for Improving Thinking, Learning, and Creativity*. New York: W. H. Freeman and Co.

Ohio Department of Education (1994). *Ohio's Competency-Based Science Model: Scientific Literacy for the 21st Century*. Columbus, OH: State Board of Education.

National Council of Teachers of Mathematics (1993). *Curriculum and Evaluation Standards for School Mathematics*. Reston, VA: NCTM.

National Research Council (1996). *National Science Educational Standards*. Washington, DC: National Academy Press.

The Secretary's Commission on Achieving Necessary Skills (1992). *Learning a Living: A Blueprint for High Performance: A SCANS Report for America 2000*. Washington, DC: U.S. Department of Labor.

APPENDIX B

Applied Technology Resources

It is important to note that some of the following books, kits, and software packages were developed for younger learners than you might be instructing. However, don't rule out using them for that reason because many of these materials can easily and effectively be adapted for use with older learners.

Resources for Instructors of Applied Technology

Activities Integrating Mathematics and Science (AIMS). Fresno, CA: AIMS.
Electrical Connections
Finding Tour Bearings
Floaters and Sinkers
Machine Shop
Math + Science, A Solution

The AIMS books provide instructors with a wide variety of hands-on activities designed to be used in grades 4-9. In many of the activities, learners are required to solve practical, everyday problems. AIMS materials are available through retailers. AIMS can be reached directly at 209/255-4094.

Amato, C. (1992). *Inventions—Breakthroughs in Science*. New York: Smithmark Publishers, Inc.

American Chemical Society (1996). *Packaging*. Dubuque, IA: Kendall/Hunt Publishing Co.
This resource presents a well-planned unit that helps learners understand what packaging does. Learners have opportunities to investigate packaging materials, math in packaging, packaging equipment, and uses of packaging. A teacher's guide and student workbooks are available. Although developed for learners in grade 6, it can be used with older learners. It is in the collection of the Eisenhower National Clearinghouse, which is described in the Suppliers of Science Resources and Materials section of this appendix. *Packaging* is one of a series of 8 activity books developed by the ACS.

Anderson, R. (1996). *Problem Solving Using the LEGO DACTA System*. Columbus, OH: Eisenhower National Clearinghouse.
This series of teacher-developed lessons for grades K-12 helps learners understand mechanical systems by building them.

Arons, A. (1990). *A Guide to Introductory Physics Teaching*. New York: John Wiley & Sons.

Bath, J. (1995). *Science Process Skills: Grades 2-5.* Greensboro, New York: Carson-Dellosa Publishing.

This instructor resource presents background and learning activities that help learners develop skills in observing, collecting information, communicating, measuring, classifying, inferring, predicting, controlling variables, representing data, hypothesizing, and experimenting. The activities can be adapted for older learners.

Butel, M., et al. (1994). *Problem Solving: Making a Difference.* Wichita, KS: Wichita State University.

This book was developed by teachers for grades 8-10 but its activities can be adapted for learners of other ages. The eight problem-solving activities included in this book include: probing a mystery box; designing a package with the smallest amount of packaging materials; designing two downhill racers with different performance; and constructing a system that travels a certain distance, reverses direction, and returns the same distance. This book is distributed by Wichita State University, 316/689-3322. It is in the collection of the Eisenhower National Clearinghouse, which is described in the Suppliers of Science Resources and Materials section of this appendix.

Carin, A. (1993). *Guided Discovery Activities for Elementary School Science, Third Ed.* New York: Macmillan Publishing Company.

Center for Mathematics, Science, and Technology Education (1995). *Manufacturing.* Normal, IL: Illinois State University.

CeMAST has developed six sequential modules that progressively increase the integration of math, science, and technology through use of hands-on activities. Developed for grade 7, *Manufacturing* is this fifth module in the series and focuses on the importance of manufacturing to society. The activities involve making a book cover and learning the operations that lead to a marketable product. The curriculum, which follows the national science standards, can be ordered from CeMAST at 309/438-3089; fax 309/438-3592. A commercial edition may also be available by the time of this printing. It is in the collection of the Eisenhower National Clearinghouse, which is described in the Suppliers of Science Resources and Materials section of this appendix.

Center for Occupational Research and Development, in cooperation with the Agency for Instructional Technology (1996). *Principles of Technology: A Contextual Approach to Workplace Physics.* Waco, TX: CORD.

Principles of Technology is a series of books designed to comprise a course in applied physics for high school students and adults who plan to pursue careers as technicians or who just want to keep pace with technological advances. The series blends an understanding of basic principles with hands-on practice in practical applications to give learners a firm foundation for understanding technology. This is an excellent resource for instructors. It contains 14 separate books, each covering a separate unit. The topics include Force, Work, Rate, Resistance, Energy, and Power. Materials can be purchased from CORD at P.O. Box 21206, Waco, TX 76702-1206; 800/231-3015.

Consell, C. (1990). *Science EQUALS Success.* Newton, MA: WEEA Publishing Center.

This resource was developed for middle-school and early secondary-school science teachers. It builds on the fun of science, motivating all students-including girls and students of color-during a critical period when many lose interest in science and math. Its over 30 hands-on, discovery-oriented, field-tested activities are designed to supplement to an existing program; each activity can stand alone. In addition to teaching basic scientific principles, EQUALS addresses problem solving, cooperative learning, spatial skills, and career awareness. EQUALS can be ordered from the WEEA Equity Resource Center by calling 800/793-5076.

Dunn, S., R. Larson (1990) *Design Technology: Children's Engineering.* New York: The Falmer Press.

This resource gives in-depth information about teaching the design process to learners of all ages.

Full Option Science System (FOSS) was developed by the Lawrence Hall of Science at the University of California, Berkeley and is distributed by Encyclopedia Britannica Educational Corporation.

The FOSS program, which comprises a comprehensive K-6 curriculum, is designed to engage learners in actively constructing scientific concepts through multi-sensory, hands-on activities. FOSS materials are available through many retailers. In addition, FOSS staff can be reached directly at 510/642-8941; fax; 510/642-1055. NOTE: Even though these materials specify grade levels, most can be easily adapted to meet the needs of older learners. FOSS materials are in the collection of the Eisenhower National Clearinghouse, which is described in the Suppliers of Science Resources and Materials section of this appendix.

Levers and Pulleys (grades 5-6)
Mixtures and Solutions (grades 5-6)
Models and Designs (grades 5-6)
Variables (grades 5-6)

Fraser, S. (1982). *SPACES: Solving Problems of Access to Careers in Engineering and Science.* Palo Alto, CA: Dale Seymour Publications.

This resource, designed for grades 4-10, integrates the principles of math and science that are required to plan the development of structures. It also incorporates the skills of logical thinking, spatial visualization, estimation, research, and career awareness. Educators may copy and use this material for noncommercial purposes. *SPACES* was developed through The Lawrence Hall of Science at the University of California, Berkeley, through a National Science Foundation grant.

Great Explorations in Math and Science (GEMS) guides were developed by the Lawrence Hall of Science at the University of California, Berkeley.
These guides, developed to be used by nonscience teachers, involves learners in hands-on, inquiry-based learning. Each guide comprises a comprehensive, ready-to-use unit on a given topic, which was designed for a range of grade levels. The following is a partial list of the units that are available from GEMS at the time this book was printed. Other GEMS titles, including those pertaining to biology, ecology, and math, are also available; new titles are being developed every year. NOTE: Even though these materials specify suitability for a given range of grade levels, most can be easily adapted for older learners. GEMS materials are available through many suppliers including William Sheridan & Associates, listed in the resource section of this book. GEMS staff can be reached directly at 510/642-7771; fax; 510/643-0309.

Acid Rain (grades 6-10)
Bubble-ology (grades 5-9)
Build It! Festival (grades K-6)
Chemical Reactions (grades 6-10)
Color Analyzers (grades 5-9)
Convection: A Current Event (grades 6-9)
Crime Lab Chemistry (grades 4-8)
Discovering Density (grades 6-10)
Experimenting With Model Rockets (grades 6-10)
Fingerprinting (grades 4-8)
Height-O-Meters (grades 6-10)
Investigating Artifacts (grades K-6)
Learning About Learning (grades 5-10)
Mystery Festival (grades 2-9)
Of Cabbages and Chemistry (grades 4-8)
Paper Towel Testing (grades 5-9)
Vitamin C Testing (grades 4-8)

Pedagogical handbooks available from GEMS are—

GEMS Teacher's Handbook
GEMS Leader's Handbook
Once Upon a Gems Guide: Literature Connections
Insights and Outcomes: Assessment for GEMS Activities
A Parent's Guide to GEMS
To Build a House : A Thematic Approach to Teaching Science

Girls, Inc. (1990). *The Power Project: Operation SMART Activity Guide.* New York: Girls Inc.
This practical, easy-to-use guide presents a solid program to encourage girls in science, math, and technology. It enables nonscience teachers to facilitate inquiry-based learning about power, simple machines, and the environment. Although developed for middle-school and high-school girls, it is a solid program for all learners including adults. It can be ordered from the Girls, Inc. Resource Center at 317/634-7546.

Girls, Inc. (1990). *Spinnerets and Know-How: Operation SMART Planning Guide.* New York: Girls Inc.

This guide lays the foundation for developing a program to encourage girls in science, math, and technology. This practical guide helps educators and others develop an effective, inquiry-based program for girls, particularly those in middle school and high school, or mixed-gender groups. Materials can be ordered from Girls, Inc. Resource Center at 317/634-7546.

Haggart, M. (1994). *Mystery Lab.* Dubuque, IA: Kendall/Hunt Publishing Co.

The Reading Is Fundamental program developed a series of books that are part of a science and reading motivation program designed to supplement existing science curricula for the upper elementary grades and to integrate science and technology through a series of laboratory investigations. Each unit explores a topic in the natural and physical sciences as well as literature. The activities help learners use the scientific method to solve a mystery. Both a teacher's guide and mentor's guide is available. It is in the collection of the Eisenhower National Clearinghouse, which is described in the Suppliers of Science Resources and Materials section of this appendix.

Hockett, A. (1996). *Red Herrings Science Mysteries: Solving Mysteries Through Critical Questioning*, Level A, Books 1 and 2. Pacific Grove, CA: Critical Thinking Books & Software, Inc.

These books, developed for learners in grades 4-6, teach students to develop questioning strategies used in the scientific method while building reading comprehension and vocabulary skills. By analyzing short mysteries that are based on scientific principles, generating hypotheses, and testing possibilities, students learn that things are not always as they appear. The books were developed to motivate learners and to provide a springboard for further investigation of scientific principles. They are in the collection of the Eisenhower National Clearinghouse, which is described in the Suppliers of Science Resources and Materials section of this appendix.

Holley, D. (1996). *Sciencewise: Discovery Scientific Process Through Problem Solving*, books 1, 2, and 3. Pacific Grove, CA: Critical Thinking Books & Software, Inc.

This three-book series provides elementary and middle school teachers with a wide variety of "Dynamic Demos" and "Creative Challenges," which include detailed instructions and discussion questions. The books were developed for nonscience teachers and require low-cost materials. The Dynamic Demos are instructor-led experiments that carefully guide learners through specific steps in order to develop their understanding of scientific process and methodology. (The demonstrations can also be modified into hands-on activities for learners.) Creative Challenges are student-centered activities that actively engage learners' creative, critical-thinking, and problem-solving skills. These books are available from William Sheridan & Associates, listed in the Suppliers of Science Resources and Materials section of this appendix, or from Thinking Books & Software at 800/459-4849. This set is in the collection of the Eisenhower National Clearinghouse, which is described in the Suppliers of Science Resources and Materials section of this appendix.

Hosking, W. (1990). *Flights of Imagination.* Washington, DC: National Science Teachers Association.

This resource provides instructions for projects that help learners experiment with 18 aerodynamics principles.

Jorgensen, M. (1993). *Assessing Habits of the Mind: Performance-Based Assessment in Science and Math.* ERIC Math, Science, and Technology Clearinghouse.

The ERIC Clearinghouse is described in the Suppliers of Science Resources and Materials section of this appendix.

Keller, C. (1979). *The Best of Rube Goldberg.* New York: Franklin Watts.

Korchin, F. (1995). *Science in the Marketplace.* Tiger Publications, 32 Friendship Ct, Red Bank, NJ 07701; 908/747-9042.

This is an excellent resource for instructors or learners who are seeking lab activities based on everyday consumer topics. The 60-plus lab topics include making cottage cheese, making soap, comparing bleaches, treating hard water, dying textiles, understanding sugars and sweeteners, and testing antacids. Suitable for grades 7-adult. Sample labs are provided on the producer's internet web site at http://www.monmouth.com/~rosin/tiger.

Main, J., P. Eggen (1991). *Developing Critical Thinking Through Science.* Pacific Grove, CA: Critical Thinking Books and Software, Inc.

Book 1 targets grades 1-4 and Book 2 targets grades 4-6. Both resources were developed to enable nonscience teachers to involve learners in hands-on discovery by using low-cost materials. These books are available from William Sheridan & Associates, listed in the Suppliers of Science Resources and Materials section of this appendix. Thinking Books & Software can be reached directly at 800/459-4849.

McCormack, A. (1981). *Inventors Workshop.* New York: Fearon Teacher Aids, Simon & Schuster Supplementary Education Group.

This resource provides instructors and/or learners with ideas for inventing a wide variety of things including inside-the-box inventions, candle-powered inventions, electrical inventions, and Rube Goldberg contraptions.

Ostlund, K. (1992). *Science Process Skills: Assessing Hands-on Science Performance.* New York: Addision-Wesley Publishing Co.

This book , developed grades 1-6, offers suggestions for assessing separate process skills, including reproducible activities and data sheets. The suggested activities can be set up in stations or conducted individually. The author believes that these activities can be used with all learners.

Ramig, J., J. Bailer, J. Ramsey (1994). *Teaching Science Process Skills.* A Good Apple Science Resource Book. New York: Good Apple Publishing Co.

This book, developed for grades 6-8, isolates each process skill and provides practice activities for teaching each skill to learners.

Rezba, R., R. Sprague, et al (1995). *Learning and Assessing Science Process Skills*, 3rd ed. Dubuque, IA: Kendall/Hunt Publishing.

This instructor resource includes a wide variety of hands-on science activities that teach process skills. Each activity is tied to specific competencies.

Sadker, M., D. Sadker (1994). *Failing at Fairness: How America's Schools Cheat Girls.* New York: Charles Scribner's Sons.

This book describes ways in which males and females are given different treatment in school and makes concrete, easy-to-do suggestions for instructors.

Sarquis, J., et al (1997). ***Investigating Solids, Liquids, and Gases With TOYS.*** Terrific Science Press. New York: Learning Triangle Press, an imprint of McGraw-Hill, Inc.

This high-quality, user-friendly resource provides complete hands-on activities for learners in the middle-school grades. The activities can be adapted for older learners.

Sarquis, M., et al (1995). ***Teaching Chemistry With TOYS.*** Terrific Science Press. New York: Learning Triangle Press, an imprint of McGraw-Hill, Inc.

This resource presents a wide variety of practical, well-planned, teacher-tested activities for teaching process skills and the principles of chemistry through discovery and critical thinking. Although designed for grades K-9, the activities are adaptable for high school and adult learners.

Scholastic Science Place (1995). *How People Invent: How Problems and Solutions Change Over Time.* New York: Scholastic.

This resource is one of a series of instructional units designed in cooperation with the Children's Museum of Memphis. This unit helps learners explore invention from the brainstorming process to the development of a working model. Lessons are grouped in 3 subconcepts—

- People use problem-solving strategies to invent new processes and devices
- New inventions and new applications of existing inventions are developed by observing and thinking about everyday occurrences
- Inventors use models to make and test new inventions and to minimize the dangers of untested technologies

Designed for grade 5, the activities are adaptable for older learners. All of the Scholastic Science Place units are in the collection of the Eisenhower National Clearinghouse, which is described in the Suppliers of Science Resources and Materials section of this appendix.

Science Education for Public Understanding (SEPUP) Program, developed by the Lawrence Hall of Science, University of California, Berkeley, is distributed by Sargent-Welch Scientific Curriculum Problems.

SEPUP is a program designed to help junior-high and high-school students learn about science in the context of societal issues. Learners collect and process scientific evidence and use it to make decisions. Modules, which cost $120-220, include a teacher's guide and all materials needed for 5 classes of 35 learners. Even though the modules primarily involve the scientific principles involved in chemistry, which is not the focus of Targets for Learning, they help learners develop critical thinking and problem solving skills, which are vital to solving problems in applied technology. A catalog that describes the SEPUP modules is available upon request. SEPUP materials can be purchased from Sargent-Welch Scientific at 800/727-4368; 708/459-6975 fax; sarwel@sargentwelch.com e-mail. They are in the collection of the Eisenhower National Clearinghouse, which is described in the Suppliers of Science Resources and Materials section of this appendix.

SEPUP modules include the following:

Chemical Survey & Solutions and Pollution
Risk Comparisons (e.g., making decisions based upon probability)
Determining Threshold Limits
Investigating Groundwater: The Fruitvale Story
Toxic Waste: A Teaching Simulation
Plastics in Our Lives
Investigating Chemical Processes: Your Island Factory
Chemicals in Foods: Additives
The Waste Hierarchy: Where is "Away?"
Household Chemicals
Investigating Hazardous Materials
Environmental Health Risks

Stenmark, J., V. Thompson, R. Cossey (1986). *Family Math*. Berkeley, CA: Lawrence Hall of Science.

This resource provides educators, parents, and learners with a wide array of activities to enhance math and problem-solving skills.

Taylor, B., et al (1995). *Teaching Physics With TOYS*. Terrific Science Press. New York: Learning Triangle Press, an imprint of McGraw-Hill, Inc.

This resource provides instructors with a wide variety of practical, well-planned, teacher-tested activities to teach process skills and the principles of physics through discovery and critical thinking. Although designed for grades K-9, the activities are adaptable for high school and adult learners.

Taylor, B. (1997). *Teaching Energy With TOYS.* Terrific Science Press. New York: Learning Triangle Press, an imprint of McGraw-Hill, Inc.

This resource includes a wide variety of practical, well-planned, teacher-tested activities to teach process skills and principles of energy through discovery and critical thinking. Although designed for grades K-9, the activities are adaptable for high school and adult learners.

TOPS Learning Systems

The following resources provide learners with thoughtfully sequenced activities to teach and reinforce specific science principles and process skills through hands-on, guided discovery. Because TOPS is a nonprofit organization, its books are inexpensive ($8-16). Most activities require low-cost, everyday materials. TOPS materials can be purchased from many suppliers, including William Sheridan & Associates, listed in the Suppliers of Science Resources and Materials section of this appendix, or from TOPS at 10970 Mulino Road, Canby, OR 97013; 503/266-8550; fax 503/266-5200; e-mail tops@canby.com.

TOPS Open-Ended Task Card Series

(Designed for 7-12 graders and adaptable for younger and older learners; each series includes 16-36 lessons and notes for teaching each lesson. The skill level is indicated beside each title.)

Pendulums	(challenging)
Measuring Length	(basic)
Graphing	(basic)
Balancing	(moderate)
Weighing	(basic)
Metric Measure	(challenging)
Math Lab	(moderate)
Probability	(basic)
Floating and Sinking	(moderate)
Analysis	(basic)
Oxidation	(basic)
Solutions	(basic)
Cohesion and Adhesion	(basic)
Kinetic Energy	(moderate)
Heat	(challenging)
Pressure	(challenging)
Light	(moderate)
Sound	(moderate)
Electricity	(challenging)
Magnetism	(challenging)
Motion	(challenging)
Machines	(moderate)

TOPS Structured Activity Sheet Series

(Designed for grades 3-10, each book includes 20 ready-to-copy lessons.)

Balancing	(basic)
Electricity	(basic)
Magnetism	(basic)
Pendulums	(moderate)
Metric Measuring	(moderate)
Focus Pocus (light and lenses)	(moderate)

Unified Science and Mathematics for Elementary Schools (USMES). Educational Development Center, 55 Chapel Street, Newton, MA 02160.

USMES is a series of 23 guides published in the early 1970s for use in grades 1-8. The units, which are listed below, focus on long-range investigations of real and practical problems geared to the local environment. Each unit consists of an opening challenge out of which learners create their own investigations—honing their problem solving skills. USMES are currently out of print. However, they are available through the ERIC Clearinghouse for Science, Mathematics, and Environmental Education, 1929 Kenny Road, Columbus, Ohio 43210-1080; 800/538-3742. Activities are adaptable to older learners.

Bicycle Transportation (grades 4-8)
Burglar Alarm Design (grades 3-8)
Consumer Research Product Testing (grades 1-8)
Designing fro Human Proportions (grades 3-8)
Electromagnet Device Design (grades 3-8)
Manufacturing (grades 4-8)
Traffic Flow (grades 1-8)
USMES Design Lab Manual (grades 1-8)

U.S. Department of Energy (1995). *Educator's Guide to Free Science Materials*, 36 ed. Randolph, WI: Educator's Press Services.

Webb, C. (1992). *Science and Technology by Design: 2*. Sydney, Australia: Harcourt Brace Jovanovich.

The activities involve investigating, designing, making, and using technology. The nearly 100 activities are organized in to 8 units, which include simple machines, structures, fibers, energy, and flight. The activities were designed for grades 4-6 and are adaptable for older learners.

Books for Learners

Although they were written for learners, the books listed below can give instructors background information about scientific principles as well as ideas for experiments that can used in the classroom.

Ardley, Neil (1991). The Science Book Series, Harcourt, Brace, and Javonovich.

This series includes books on many science topics including the following:

The Science Book of Air
The Science Book of Color
The Science Book of Water

Ardley, Neil (1993). *101 Great Science Experiments: A Step-by-Step Guide.* London: Dorling Kindersley Limited.
This resource presents background information and activities that demonstrate physical science principles as they relate to topics such as air and gases, water and liquids, hot and cold, color, magnets, electricity, and motion and machines.

Ardley, Neil, et al (1984). *How Things Work.* New York: Simon and Schuster, Inc.
This book provides readers with simple explanations for how things such as flashlights, magnets, car batteries, electric motors, transformers, electromagnets, and fire extinguishers work.

Barber, N., T. Keegan (1990). *175 More Science Experiments.* New York: Random House.

Caney, S. (1980). *Steven Caney's Invention Book.* New York: Workman Publishing.
This resource gives instructors and learners many examples of inventions that have been and/or can be developed.

Carow, R. (1996). *Put a Fan in Your Hat!: Inventions, Contraptions, and Gadgets Kids Can Build.* New York: Learning Triangle Press, an imprint of McGraw-Hill, Inc.

Gardner, R. (1990). *Investigate and Discover Forces and Machines.* New York: Franklin Institute Science Museum.

Gateway Simple Machines Series includes the following titles:

Inclined Planes
Levers
Pulleys

Goodwin, P. (1994). *More Engineering Projects for Young Scientists.* New York: Franklin Watts.

Hann, J. (1991). *How Science Works.* Pleasantville, New York: Reader's Digest.
Helpful for learners, instructors, and parents, this well-illustrated book of activities and information is organized around basic science topics.

Kerrod, R. (1990). *How Things Work.* New York: Marshall Cavendish Publishing.

Kohl, M. A., J. Potter (1993). *Science Arts: Discovering Science Through Art Experiences.* Bellingham, WA: Bright Ring Publishing.

This resource provides opportunities for learners of ages 3-14 to gain experience with many scientific principles related to air and water; light and sound; motion and energy; and reaction and matter.

Lafferty, P. (1991). *What's Inside? Great Inventions.* New York: Dorling Kindersley.

Laux, K. (1997). *The World's Greatest Paper Airplane and Toy Book.* New York: Learning Triangle Press, an imprint of McGraw-Hill, Inc.

MacCaulay, D. (1988). *The Way Things Work.* Boston: Houghton Mifflin Company.

Ontario Science Center (1986). *Sportsworks: More than 50 Fun Activities that Explore the Science of Sports.* Reading, MA: Addison Wesley Publishing Company.

Ontario Science Center (1986). *Scienceworks.* Reading, MA: Addison Wesley Publishing Company.

Sauvein, P. (1992). *The Way It Works.* New York: New Discovery.

Sobey, E. (1996). *Wrapper Rockets and Trombone Straws: Science at Every Meal.* New York: Learning Triangle Press, an imprint of McGraw-Hill, Inc.

Taylor, B. *Steps into Science Series.* New York: Random House Publishing. Titles in this series include the following:

Get It In Gear: The Science of Movement
Over the Rainbow: The Science of Color and Light
Up, Up & Away!: The Science of Flight

VanCleave, J. has written many science books, published by John Wiley & Sons, Inc., including the following:

Chemistry for Every Kid: 101 Easy Experiments that Really Work
Gravity: Mind-boggling Experiments You Can Turn Into Science Fair Projects
Machines: Mind-boggling Experiments You Can Turn Into Science Fair Projects
Magnets: Mind-boggling Experiments You Can Turn Into Science Fair Projects
Physics for Every Kid: 101 Easy Experiments in Motion, Heat, Light, Machines, and Sound
200 Gooey, Slippery, Slimy, Weird & Fun Experiments
200 More Gooey, Slippery, Slimy, Weird & Fun Experiments

Wellnitz, W. (1993). *Homemade Slime and Rubber Bones!: Awesome Science Activities.* New York: Learning Triangle Press, an imprint of McGraw-Hill, Inc.

Wood, R. (1996). *Mechanics FUNdamentals: FUNtastic Science Activities for Kids.* Terrific Science Press. New York: Learning Triangle Press, an imprint of McGraw-Hill.

Wood, R. (1992). *39 Easy Engineering Experiments.* New York: Tab Books.

Zubrowski, B. has written many science books in the Boston Children's Museum Activity Book Series, published by Beech Tree Paperback Books, Inc.

Balloons: Building and Experimenting With Inflatable Toys
Blinkers and Buzzers: Building and Experimenting With Electricity and Magnetism
Bubbles
Building and Experimenting With Models of Machines
Inks, Food Colors, and Papers
Messing Around With Baking Chemistry
Messing Around With Drinking Straw Construction
Raceways: Having Fun With Balls and Tracks
Tops: Building and Experimenting With Spinning Toys
Wheels at Work: Building and Experimenting With Models of Machines

Instructional Kits

The following kits contain all of the information and some or all of the materials that instructors would need to teach a unit. In addition to those listed below, science suppliers (such as Delta Educational) sell kits about a wide variety of topics (e.g., simple machines). Also, William Sheridan & Associates develops customized kits upon request. Information about these retailers is provided in the Suppliers of Science Resources and Materials section of this appendix.

MacMillan/McGraw-Hill Science Program. *Using Energy; Changes in Matter*, and *Forces at Work*

Each kit includes 42 self-contained, thematic science units for grades K-8. MacMillan/McGraw-Hill can be reached at 800/442-8815.

Scholastic Science Place Program. *How People Invent: How Problems and Solutions Change Over Time.* New York: Scholastic. This kit is described in the Resources for Instructors of Applied Technology section of this appendix.

Science Education for Public Understanding (SEPUP) Program, developed by the Lawrence Hall of Science, University of California, Berkeley, is distributed by Sargent-Welch Scientific Curriculum Problems. These kits are described in the Resources for Instructors of Applied Technology section of this appendix.

Society of Automotive Engineers. *A World in Motion II: The Design Experience.*

This multidisciplinary unit is one of three engineering-design challenges that take the form of real-world design scenarios. Although developed for seventh graders, it can easily be adapted for younger or older learners. Each challenge focuses student design teams, instructors, and volunteers from the professional community on the math, science, and technological concepts required to solve a design problem over an 8-week period. In this unit, learners develop a motorized, gear-driven toy. Through hands-on activities, students learn about energy, force, friction, simple machines, levers, gears, and torque. A teacher's manual, a teacher concept video, a CD-ROM, 2 posters, and a video set are available for $85 from the SAE at 800/456-2946; fax 412/776-2103; http://www.sae.com. It is in the collection of the Eisenhower National Clearinghouse, which is described in the Suppliers of Science Resources and Materials section of this appendix.

Instructional Computer Software and Laser Disks

There are many software packages on the market. However, many of these are not much more than a workbook of drills designed to reinforce basic skills. Educators and parents are encouraged to select software that encourages learners to **develop critical thinking and problem-solving skills**. The following software packages meet this criteria.

The Learning Company, Inc.

The following software packages were developed by The Learning Company. Each helps learners build their understanding of basic mathematical or science principles. In addition, each package gives learners many opportunities to do hands-on experimentation, deductive reasoning, and real-world problem solving. The age range for each software package appears below. The author believes that learners of any age will enjoy using these materials. This software can be purchased from retailers or directly from The Learning Company at One Anthenaeum Street, Cambridge, MA 02142; 800/227-5609

Integrated Math and Science Problem Solving:

Super Solvers OutNumbered! (ages 8-10)
Super Solvers Gizmos & Gadgets! (ages 8-10)
Operation Neptune (ages 10 and up)

Thinking and Problem Solving:

Logic Quest (ages 10 and up)

Museum Madness

Developed for learners in grades 5-8, this software gives learners opportunities to build higher-order thinking skills, increase reading comprehension, and stimulate interest in the topics that are covered. The setting is a local museum where learners experience history and historical people. Learners must employ logic and problem-solving skills as they respond to strange happenings at the museum. This software is distributed by Minnesota Educational Computing Corporation, 6160 Summit Drive North, Minneapolis, MN 55430; 800/685-6322; fax 612/569-1551; http://www.mecc.com. It is in the collection of the Eisenhower National Clearinghouse, which is described in the Suppliers of Science Resources and Materials section of this appendix.

Real World Problem Solvers: The Garbage Dump Dilemma

Developed for grades 5-10, this laserdisc kit presents a role-playing simulation in which learners must weigh alternatives rather than look for one right answer. In the story, participants learn of a proposal to expand a landfill by way of eminent domain—an expansion that would destroy a family farm. The National Teachers of Mathematics developed this videodisc kit, which won a Solver Apple award at the 1993 National Educational Film and Video Festival. The kit is distributed by Human Relations Media, 800/431-2050. It is in the collection of the Eisenhower National Clearinghouse, which is described in the Suppliers of Science Resources and Materials section of this appendix.

Science Sleuths: Volume 1, The Mysteries of the Blob and the Exploding Lawn Mowers
Volume 2, The Mysteries of the Biogene Picnic and The Traffic Accident

These CD-ROMs are part of the Science Sleuths series, which was developed for grades 6-12. Learners must analyze and solve mysteries by using the research methods and tools that scientists use. Users begin the program as an apprentice, earning promotions as they progress through the program's difficulty levels. This software is distributed by Videodiscovery, Inc., 800/548-3472. It is in the collection of the Eisenhower National Clearinghouse, which is described in the Suppliers of Science Resources and Materials section of this appendix.

Strategy Challenges, Collections 1 and 2

This software package, which is appropriate for grades 4-12, encourages strategic planning and problem solving, although it does not target any specific discipline. By way of a wide variety of games and activities, learners use the problem-solving process to confront real-life situations that require critical thinking. This software was field tested and rated very highly by teachers participating in the Ohio SchoolNet Plus Software Review Project. The package is distributed by Edmark Corporation, P.O. Box 97012, Redmond, WA 98073; 800/362-2890; fax 206/556-8430; edmarkteam@edmark.com. It is in the collection of the Eisenhower National Clearinghouse, which is described in the Suppliers of Science Resources and Materials section of this appendix.

Thinking Like a Scientist: Process Skills and Critical Thinking

Developed for learners in grades 4-6, this software uses colorful graphics and animations that allow students to discover how to use science to make decisions and think critically. Topics include correcting faulty problem statements, designing experiments, interpreting graphs, and making predictions based on patterns, probability, and sample information. This software is distributed by Educational Activities, Inc., P.O. Box 329, Freeport, NY 11520; 800/645-3739; fax 516/623-9282. It is in the collection of the Eisenhower National Clearinghouse, which is described in the Suppliers of Science Resources and Materials section of this appendix.

Widget Workshop: The Mad Scientist's Laboratory

This software package, designed for grades 6-8, is a science construction kit that enables learners to design and build mechanical inventions (e.g., puzzles, machines) using simulated parts. The package is distributed by Maris Multimedia, Ltd., 2 Theatre Square, Suite 2302, Orinda, CA 94563-3346; 800/336-2947; fax 510/253-3736. It is in the collection of the Eisenhower National Clearinghouse, which is described in the Suppliers of Science Resources and Materials section of this appendix.

Suppliers of Science Resources and Materials

Burt Harrison & Company

Burt Harrison & Company is a wonderful source for batteries and bulbs activities. In addition to the basic electricity-related supplies, Burt has developed and sells activity cards, motor kits, and more. They can be reached at P.O. Box 732, Weston, MA 02193; 617/647-0674.

Center for Occupational Research and Development (CORD)

CORD develops and distributes applied math and applied science materials, as described in the Resources for Teachers and Trainers of Applied Technology section of this appendix. CORD can be reached at P.O. Box 21206, Waco, TX 76702-1206; 800-231-3015.

Delta Education

Delta Education has a wide variety of science materials that can be used in hands-on science activities. Delta also carries many kits on topics such as electricity, bubble science, color and light, electromagnetism, lenses and mirrors, and simple machines. The company can be reached at P.O. Box 3000, Nashua, NH 03061; 800/442-5444.

ERIC Clearinghouse for Science, Mathematics, and Environmental Education

The ERIC clearinghouse maintains a comprehensive database on science, mathematics, and environmental education. ERIC also publishes brief summaries of research findings and practices related to science, math, and technology education. It is located at 1929 Kenny Road, Columbus, Ohio 43210-1080; 800/538-3742.

Eisenhower National Clearinghouse for Mathematics and Science Education (ENC)

The ENC was established to help K-12 teachers locate and examine useful teaching materials. The clearinghouse maintains many types of materials (e.g., books, software programs, videodiscs, kits) at its repository at The Ohio State University in Columbus. Teachers can make an on-site examination of these materials. ENC also publishes reviews of instructional materials, which can be accessed on line. In addition, reference librarians provide individualized consultations. The ENC reference desk can be reached at 1929 Kenny Road, Columbus, OH 43210-1079; 800/621-5785 or 614/292-7784; fax 614/292-2066; e-mail info@enc.org.

Great Explorations in Math and Science (GEMS)

GEMS develops materials and provides in-service training to educators on topics concerning inquiry-based science and math. This organization does much of their work through regional support centers/network sites. The GEMS materials noted on the resource list can be obtained from William Sheridan & Associates (listed in this section of the appendix) or directly from GEMS. GEMS staff can be reached at the Lawrence Hall of Science, University of California, Berkeley, CA 94720-5200; 510/642-7771; fax 510/643-0309.

Junior Engineering Technical Society (JETS)

JETS provides resources and programs for middle-school and high-school teachers and students. Inquiries should be addressed to 1420 King Street, #405, Alexandria, VA 22314-2715, and be accompanied by a stamped, self-addressed envelope.

National Science Foundation (NSF)

NSF has a toll-free number to call for answers to questions about science. The NSF also distributes learning materials and awards grants to educators. The foundation can be reached by calling 800/682-2716 or through its Internet home page at http://www.nsf.gov/od/lpa/nstw/quests/start.htm.

Technological Studies at the College of New Jersey

The College of New Jersey provides several resources for teachers of technology, as follows:

- The magazine, ties, supports technology education and the integration of math, science, and technology in middle school through high school. Published six times a year, ties is free to educators.
- Technology instructors can learn more about teaching design, problem solving, and technology by watching any of 70 videos that address topics such as design; drawing and modeling; materials and process; control and electronics; machines and mechanisms; and the teaching of design and technology.
- Subscribe to ties magazine or order videos by contacting the College of New Jersey at 103 Armstrong Hall, Hillwood Lakes, CN 4700, Trenton, NJ 08650-4700; 609/771-3333; fax 609/771-3330; e-mail ties@tcnj.edu.

Women's Educational Equity Act (WEEA) Program's Publishing Center

WEEA distributes a wide variety of materials about topics related to educational equity, including disabilities, gender equity, careers, history, math, science, and technology. A catalog and/or materials can be obtained from WEEA at 55 Chapel Street, Suite 224, Newton, MA 02158-1060; 800/793-5076; e-mail WEEApub@EDC.org. This organization's Internet address is http://www.edc.org/CEEC/WEEA.

William Sheridan & Associates

William Sheridan & Associates carries a wide variety of science, math, and language arts materials. The company also offers a plethora of written resources including most all of those listed on the previous pages. Sheridan also creates custom-designed kits on a wide variety of science topics. Bill Sheridan and his staff provides friendly, personal service and can obtain nearly anything you need. Sheridan has several catalogs of its own, and also supplies the materials found in the Basic Science, Flinn Scientific, and Connecticut Valley Biological catalogs. If you're in the area, visit Sheradin's Discovery Store, with an adjacent training classroom, just north of Columbus at 8311 Green Meadows Drive N., Lewis Center, OH 43035; 800/433-6259 or 614/548-0575; fax 614/548-0485.

Internet Sites

Ask ERIC Lesson Plans	gopher://ericir.syr.edu:70/11/Lessons/Science
Bill Nye, The Science Guy	http://www.nyelabs.kcts.org/
Clearinghouse for Mathematics and Science Education	http://www.nsta.org
The Exploratorium Science Snackbook	http://www.exploratorium.edu/publications/Snackbook/Snackbook.html
Implementing Science Education Standards	http://cedar/cic/net/ncrel/sdrs/areas/issues/content/cntareas/science/sc300.htm
Improving Math & Science Education	http://www.learner.org/content/k12
Issues in Science and Technology	http://www.utdallas.edu/research/issues/
Lawrence Hall of Science	http://www.lhs.berkeley.edu/
McGraw-Hill Publishers	http://www.mcgraw-hill.com
National Science Foundation	http://www.nsf.gov
National Science Education Standards	http://www.nap.edu/readingroom/
National Science Teachers Association	http://www.nsta.org
Newton's Apple Educational Materials	http://ericir.syr.edu/Newton/welcome.html
NPR Science Friday Kids Connection	http://www.npr.org/sfkids/index.html
The Science Club	http://www.halcyon.com/sciclub/
Science Education Resources	http://www.edu/intec/science.html
Science, Technology, and Society Links	http://gpu2.srv.ualberta.ca/~slis/guides/scitech/kmc.htm/
U.S. Department of Energy	http://www.doe.gov

APPENDIX C

Basic Scientific Principles

Applied technology focuses on:

- Principles related to *power sources*—for mechanical, electrical, thermal, and fluid systems
- Principles related to *flow*—for mechanical, electrical, thermal, and fluid systems
- Principles related to *pressure*—for mechanical, electrical, thermal, and fluid systems
- Principles related to *resistance*—for mechanical, electrical, thermal, and fluid systems

The basic scientific principles involved with energy sources, flow, pressure, and resistance appear below:

Bernoulli's principle: The faster the flow of air or fluid, the lower the pressure.

Boyle's law: Pressure is affected by the force exerted on a unit of the surface—the smaller the surface, the greater the pressure (given the same force and a constant temperature).

Charles' law: If a gas' temperature is raised, its volume also increases by the same ratio (providing its pressure remains constant). Or, if a gas' temperature is raised, its pressure increases by the same ratio (providing its volume remains constant).

Hooke's law: The greater the force exerted on an object, the more it will be moved. For example, the heavier the weight hanging from a spring, the more the spring will be stretched.

Newton's laws of motion

- An object will remain at rest or in uniform motion unless acted upon by an outside force.
- When a force acts upon an object, it changes the momentum of that object, and this change is proportional to the applied force and to the time that it acts upon the object.
- Every action (i.e., force) is followed by an equal and opposite reaction (i.e., force).

Laws of Thermodynamics

- Energy cannot be created or destroyed.
- Heat energy always flows spontaneously from hot to cold.

Ohm's law: Current is directly proportional to the voltage and inversely proportional to the resistance (Refer to page 331 for additional information).

Pascal's law: Pressure added to a confined fluid at any point instantly appears equally at all other points, and is always at right angles to the containing surfaces.

Generalizations that can be made about mechanics:

A **machine** is something that does work.

Work is done when a force causes an object to move.
Simple machines (e.g., gears, pulleys, inclinded planes, levers, wheel and axle), which are described below, make up compound (or complex) machines.

Compound machines include a bicycle, a rod and reel, a typewriter, a can opener, a scissors, a hand drill, a car, a weight machine, and a treadmill.

Gears

- The force that is applied to a driver gear is transferred to a driven gear.
- When two gears of different sizes are meshed together, the smaller gear turns faster (more rotations per minute) than the larger gear.
- Gears that are side-by-side and meshed together move in opposite directions.
- The direction and speed of the driver gear determines the speed and direction of gears that are meshed with it.

Pulleys

- A pulley is a wheel with a rope, belt, or chain around it.
- Pulleys change the direction of movement and make work easier.
- Fixed pulleys change the direction that something is moved; they do not make work easier.
- Moveable pulleys change the direction that something is moved and make work easier.
- The more pulleys in the system, the easier it is to do work (e.g., pull or lift an object).
- The more pulleys involved in a system, the greater distance must be pulled, but the easier it is to do work.
- The thinner the windlass, the easier it is to turn.
- In two different sets of pulleys, if the wheels are connected by a shaft and the two wheels on one pulley are the same size as the two wheels on the other pulley, they will both turn at the same speed.
- Common pulleys include crankshafts, sailboats, and window blinds.

Inclined Planes

- An inclined plane is a slanted surface that is used to raise or lower heavy objects from one position to another.
- Inclined planes help reduce the amount of force needed to do a given amount of work, but require greater distance.
- The steeper the plane, the more difficult the work.
- Wedges are two back-to-back inclined planes.
- Common inclined planes are a screw, a bolt, a drill bit, a clamp, a car jack, and a bottle top.

Levers

- A lever is a bar or rod that is free to move or turn on a fulcrum.
- A lever multiplies force, but some distance must be given up.
- The shorter the effort arm, the less force is attained and the greater distance is attained.
- The longer the effort arm, the more force is attained and the less distance is attained.
- Examples of levers include scissors, a broom, a claw hammer, a nutcracker, a mop, tongs, a crowbar, a can opener, tweezers, a baseball bat, boat oars, and a car jack handle.

Wheel and Axle

- A wheel and axle is like a spinning lever (e.g., an ice cream machine crank).
- The center of the axle is the fulcrum.
- The wheel is larger than the axle; the wheel turns a greater distance than the axle turns. Work is done at the wheel and is multiplied at the axle.
- Common wheel and axles include a screwdriver, roller skates, a water faucet handle, a bicycle pedal, a can opener, a car steering wheel, and a clock.

Overview of Electricity

Electricity is the continuous flow of electrons, or **current**, from one atom to another. No electron flow will occur unless there is a pathway over which the electrons can move. This flow is similar to a water system, where pipes or hoses move water from storage tanks to where it is needed. In electrical wiring, the pathway through which electrical current flows is called a **circuit**. A simple circuit consists of a power source, conductors, load, and a device for controlling current. Each is described below.

- In buildings, the **power source** could be considered the electrical generating stations that pump electricity into residential and commercial buildings. However, primary sources of electrical power include small generators and batteries.
- **Conductors**, or wiring, provide a path for the current so that it can travel from one point to another.
- A **load** is a device through which electricity produces work. For example, a lamp is a load that, when plugged in and turned on, produces light. Other examples of loads include heaters, electric motors, and televisions.
- **Switches** (e.g., on-off switches) control when electrical current flows through circuits. **Fuses** and **circuit breakers** are protective devices that control current by preventing too much current from flowing in the circuit, which would damage equipment. When an excessive amount of electricity passes through them, fuses and circuit breakers "blow" to stop the flow of electricity through the circuit.

In a circuit, **resistance** lowers the amount of electrical energy available to do work. Both wires and load affect resistance. It might be helpful to think of a similar situation with a hose that is connected to two sprinklers. As water passes through a hose, turns or kinks in the pathway cause friction (which is resistance) that results in a slower flow. In addition, when some of the water is diverted to the first sprinkler (which is a load), less water is available for use in the second sprinkler.

There are two ways or methods of having current flow. Current is either **direct** (flowing in on direction) or **alternating** (flowing in one direction, then reversing to the other direction approximately 60 times per second). In most cases, direct current is provided to equipment by batteries (e.g., flashlights, portable radios, and cars). Alternating current is provided to equipment through electrical systems in buildings.

Measurement of Electric Current

The *rate* at which electricity flows is called **amperage**. It is measured in **amperes**. A 100-watt bulb requires a current of approximately 1 ampere to make it light up completely. Current flow is measured with an **ammeter**. Most heating and power equipment indicates the amount of current needed to operate it properly.

Measurement of Electrical Pressure

Pressure is applied to electrons to force them to move through a conductor and around a circuit. This pressure is measured in **volts**. The pressure, or **voltage**, is available in wiring circuits all of the time—whether or not electrical equipment is being used. Voltage is measured with a **voltmeter**.

Calculation of Power

The amount of *power* derived from an electrical device or system is its **wattage**. In other words, it is the product obtained from electrical energy; it is the power that we put into use. For example, the electric company sells electrical energy. Electrical energy or power is measured in watts and can be calculated as follows:

For direct-current circuits: volts x amperes = watts

For alternating-current circuits: volts x amperes x power factor = watts

NOTE: Power factors range from 0-1. Large equipment (e.g., an electric heater) may have a power factor as high as 1; small equipment (e.g., a small engine) may have a power factor as low as .25.

Ohm's Law

Ohm's law is a simple formula used to describe the relationship between current (flow), voltage (pressure), and resistance of an electrical circuit. Each component interacts to affect the operation of a circuit. In other words, because voltage pushes current through a resistance, a change in any of the components will result in a change in the others. The following three equations are Ohm's law rearranged to solve for each of the quantities:

Current = Voltage ÷ Resistance	I = E/R
amps = volts ÷ ohms	An increase in voltage causes an increase in electrical current flow. An increase in circuit resistance causes a decrease in electrical current flow.
Voltage = Current x Resistance	E = I x R
volts = amps x ohms	An increase in current causes an increase in voltage. An increase in resistance causes an increase in voltage.
Resistance = Voltage ÷ Current	R = E/I
ohms = volts ÷ amps	

Generalizations that can be made about electricity:

- The longer the wire, the greater the resistance; the thinner the wire, the greater the resistance.
- An increase in temperature of a wire causes an increase in resistance.
- An ordinary electrical cord has two wires; one for the flow of current from the power source and the other for the return or ground.
- The voltage (pressure) and current (flow of electricity) directly affect how much power is available to do work. Less energy source or lower flow will result in less electrical power being produced and vice versa.
- A series circuit has only one path for the flow of current. In a series circuit, objects are placed one after another and the current flows through each of them in succession. The current is the same throughout, however, and the voltage is divided among the objects in the circuit.
- In a parallel circuit, there are 2 or more paths, or branches, for the flow of current. The current will divide and flow through each of the paths simultaneously. Every branch has the same voltage and—if the appliances are all the same—will have the same amount of current. The total circuit resistance is less then any one branch.
- When batteries are connected in a series, the current is the same; the total voltage is the sum of the voltage of each battery. The terminals are connected +, -, +, -, and so on.
- When batteries are connected in parallel, the total current is the sum of the currents in each battery; the total voltage is the same as that of one cell. The terminals are connected +, +, +, and -, -, -.

Generalizations that can be made about heat:

- Heat travels through conductors (e.g., metal) better than through insulators (e.g., wood).
- Dark-colored surfaces absorb more heat than light-colored surfaces.
- Rough or dull surfaces absorb more heat than smooth or shiny surfaces.
- When friction causes heat, the object that is in constant contact gets hotter than the movable object. (For example, the wood being cut gets hotter than the saw blade; car brake shoes get hotter than the wheel.)

Generalizations that can be made about fluids:

Pressure

- The amount of pressure exerted by a fluid depends upon the height and the density of that fluid and is independent of the shape of the container that is holding the fluid.
- The deeper the fluid, the greater the pressure it exerts.
- The denser the fluid, the greater the pressure it exerts (e.g., salt water is denser than fresh water).
- Fluids seek equilibrium—they seek their own level; a fluid will flow from a place of high pressure to a place of of low pressure.
- A fluid can never rise higher than its source without an external force (e.g., a pump).

Evaporation

- The higher a liquid's temperature, the faster it will evaporate.
- The lower a liquid's pressure, the faster the liquid will evaporate.
- The more area of a liquid that is exposed to air, the faster the liquid will evaporate.
- The more circulation of air above a liquid, the faster the liquid will evaporate.

Boiling Point

- Increased pressure on a liquid raises the liquid's boiling point.
- Decreased pressure on a liquid lowers the liquid's boiling point.

APPENDIX D

Selected Sixth-Grade Science Proficiency Outcomes

(Outcomes That Are Relevant to Applied Technology)

Strand I — Nature of Science; learners' thinking habits in investigating science ideas.

1. *Use a simple key to classify objects, organisms, or phenomena.* Learners should be able to classify or identify objects according to shared characteristics or attributes (e.g., structure, function, shape, state of matter) using a simple key (e.g., dichotomous key, flow chart, key in table or chart format).
2. *Identify the potential hazards and/or precautions involved in scientific investigations.*
3. *Make inferences from observations of phenomena and/or events.*
4. *Identify the positive and/or negative impacts of technology on human life.*
5. *Evaluate conclusions based on scientific data.*

Strand II — Physical Science; physical and chemical principles that can be observed and explored, and the inferences that can be made, based on concrete experiences that can be observed without complicated instruments or theories.

6. *Recognize the advantages and/or disadvantages to the user in the operation of simple technological devices.* "Mechanical advantages" refers broadly to a device's mechanical advantage, or the ratio of the output forces produced by a machine to the applied input force (for example, the use of various ramps to lift boxes).
7. *Predict the influence of the motion of some objects on others.* Learners should have a basic understanding of Newton's laws of motion, which are listed in Appendix C.
8. *Propose and/or evaluate an investigation of simple, observable physical or chemical changes.*
9. *Provide examples of transformation and/or conservation of matter and energy in simple physical systems.* Learners should be able to identify what type of energy transformation is occurring, describe how energy is conserved, and/or how it can be converted into other matter plus energy (e.g., combustion). Learners should have a basic understanding of potential and kinetic energy; the main forms of energy (electrical, mechanical, thermal, chemical, and nuclear); various types of energy conversions (conversion of matter to energy, and energy to matter) and the laws of conservation of matter and energy.
10. *Identify simple patterns in physical phenomena.* Examples include the elasticity and/or compressibility of materials; the reflection and refraction of light and waves; and the production of sounds.

Selected Ninth-Grade Science Proficiency Outcomes

(Outcomes That Are Relevant to Applied Technology)

1. *Devise a classification system for a set of objects or a group of organisms.* In other words, learners should use common characteristics in grouping the items.
2. *Distinguish between "observation" and "inference" given a presentation of a scientific situation.* In other words, learners should be able to tell the difference between facts and observations, and the assumptions that are made based upon those facts and observations.
3. *Identify and apply science safety procedures.*
4. *Demonstrate an understanding of the use of measuring devices, and report data in appropriate units.*

5-7 (Earth and space science; not included in applied technology)

8. *Apply the use of simple machines to practical situations.* Learners should be able to use simple machines, such as levers, pulley systems, and inclined planes, and describe how they can make a task easier.
9. *Apply the concepts of force and mass to predict the motion of objects.* (See description in Sixth-Grade Outcome #7.)
10. *Apply the concepts of energy transformation in electrical and mechanical systems.* Learners should be able to distinguish between different forms of energy, such as chemical, electrical, and thermal; potential and kinetic. For example, learners should be able to describe how the energy in a flashlight battery is transformed into heat and light.
11. *Apply the concepts of sound and light waves to everyday situations.* For example, learners should be able to describe how sound and light travel through different materials.
12. *Describe chemical and/or physical interactions of matter.* For example, learners should be able to describe how a cube of sugar dissolves in water, how metal rusts, and how things burn.

13-16. (Life science; not included in applied technology)

17. *Describe the way scientific ideas have changed, using historical events as examples.*
18. (Earth and space science; not included in applied technology)
19. *Describe the relationship between technology and science.* For example, learners should be able to discuss how science and inventions affect each other.
20. (Life science; not included in applied technology)

Selected Twelfth-Grade Science Proficiency Outcomes

(Outcomes That Are Relevant to Applied Technology)

1. *Trace energy transformation and/or apply the principles of mass/energy conservation to physical and biological systems.* Learners should be able to follow the flow of energy in a given system and identify changes in the forms of energy within that system.
2. (Chemistry; not included in applied technology)
3. *Use fundamental forces to explain and make predictions about motions and changes in systems.* Learners should be familiar with the relationship between changes in the motion of an object and the forces applied to the object and the mass of the object. For example, learners should be able to explain how the path of a thrown ball can be predicted and why the ball falls toward the ground.
4. *Analyze the results of changing a component of simple systems.* For example, learners should explain and predict how a change can affect a mechanical or electrical system.
5. *Relate structure and function in physical (and biological) systems.* Learners should be able to recognize and have a basic understanding of the shape, material properties, position, and durability of components of systems as related to function.
6. (Earth science; not included in applied technology)
7. (Evaluation of persuasive communication; not included in applied technology)
8. *Formulate an experimental design to test a given hypothesis.* For example, learner should be able to design and conduct an experiment that tests an idea.

9-11. (Earth science; not included in applied technology)

12. *Demonstrate an understanding of units of measure and precision by using an appropriate measuring device for an application.* For example, learners should be able to identify the appropriate instrument needed to make a given measurement and to make accurate measurements.

13-18. (Life science and earth science; not included in applied technology)